

E. J. Cawson

SPECIAL REPORT

FLOOD OF MARCH 2, 1938, IN REGION 10

SOUTHERN CALIFORNIA

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147-7-2-1938(4-1)
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LOS ANGELES COUNTY FLOOD CONTROL DISTRICT
LOS ANGELES, CALIFORNIA

C. H. HOWELL
CHIEF ENGINEER

751 SO. FIGUEROA ST.

April 22, 1938.

603 CIVIC CENTER BUILDING
205 SOUTH BROADWAY

PLEASE REFER TO FILE NO. 2-3B

SUBJECT Operation of Flood
Control Structures, Storm of
March, 1938.

E. H. Howell
Honorable Board of Supervisors,
L. A. Co. Flood Control District,
501 Hall of Records,
Los Angeles, California.

Dear Sirs:

The following is in accord with your order of March 17th, 1938. It called for a report on the operation of structures in the Comprehensive Flood Control System during the March 1938 storm.

This storm was the most severe which has occurred since the organization of the District.

DAMS.

(1) The storm showed up no weakness in any of the District's dams themselves.

(2) Erosion, sufficient to require repairs, occurred below the spillway of San Gabriel Number 1, Pacoima, Sawpit, Eaton and San Dimas Dams.

This erosion in no way affected the stability of the dams.

The Pacoima, Sawpit and Eaton spillway require repair work before next flood season for the protection of the structures themselves.

The flow over the spillway of San Gabriel Dam Number 1 washed out all loose material in Brown's Gulch below the spillway.

Some minor repair work will be needed under the bottom of the concrete slope protection near the lower end of the gulch.

In designing this spillway, it was proposed to gunite or concrete the rock below the lip of the spillway proper, if and when the loose material was washed away.

As stated above, this occurred during the recent storm. Therefore, the above work will be done this season.

April 22, 1938.

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Operation of Flood
Control Structures, Storm of
March, 1938.

Honorable Board of Supervisors,
L. A. Co. Flood Control District,
501 Hall of Records,
Los Angeles, California.

Dear Sirs:

The following is in accord with your order of March 17th, 1938. It refers to a report on the operation of structures in the Comprehensive Flood Control System during the March 1938 storm.

This report was the most severe which has occurred since the organization of the District.

(1) The report showed up no weakness in any of the District's dams themselves.

(2) Some minor deficiencies in regard to gates, occurred below the spillway of San Gabriel Number 1, between the gate and San Lucas Dam.

This action in no way affected the stability of the dam.

The fact that gates and spillway gates were not closed for the purpose of the protection of the structures themselves.

The flow over the spillway of San Gabriel Number 1 was not over 11,000 cfs. in the spillway.

Some minor repairs will be needed under the bottom of the concrete spillway at the lower end of the spillway.

In designing this spillway, it was proposed to raise the concrete the rock below the lip of the spillway proper. It was when the lower material was washed away.

It is noted above that the spillway was not closed. Therefore, the above spillway was not closed.

April 22, 1938.

(3) The capacity of the outlet works at Pacoima, Tujunga and Santa Anita proved to be too small for efficient handling of storms as large as this one.

The lower outlet at Pacoima; the intake to the operating mechanism at Tujunga; and both valves at Santa Anita became plugged with debris.

At San Gabriel Dam Number 1, debris plugged approximately 10% of the trash rack area.

The trash rack at San Dimas Dam was partially wrecked and washed through the outlet.

The lower valve at Pacoima is under 13 feet of debris.

The lower valve at Santa Anita is under 37 feet of debris, the upper valve under about 17 feet.

So far we have been unable to free the Santa Anita valves.

It is believed that the plugging of these valves was largely due to the fish screens with which the outlets were equipped, in accordance with instructions issued by the State Fish and Game Commission.

The valves at Tujunga are now in operating condition.

The valve at Sawpit Dam was plugged but is now open.

All other outlets worked all right.

The outlet work at San Gabriel Dam Number 1 was not finished at the time of the storm. It is not finished yet.

A slide of loose material from the South Canyon closed the Azusa Conduit Sand Box, but did not injure the outlet works.

Reports that the end of the tunnel was plugged and that the penstocks were damaged, are not true.

(4) The following table shows the approximate percentage loss in storage capacity due to debris:

LA Pacoima	9
LA Tujunga	24
LA Devil's Gate	25
SA *Eaton	26
SA *Sierra Madre	82
*Sunset	64
SA Santa Anita	33
SA Sawpit	18
SA-San Gabriel #2	12
SA-San Gabriel #1	6-10 (estimated only)
SA-Big Dalton	9
SA-San Dimas	18
SA Live Oak	7
SA-Thompson Creek	3 SJ
SA Puddingstone	0 SJ

*Eaton, Sierra Madre and Sunset Dams were built primarily for debris detention and not flood control purposes.

It is relatively a simple matter, although an expensive one, to clean out the material above debris dams and above Devil's Gate, Live Oak and Thompson Creek Reservoirs. This because they are so located that excavating equipment can be moved into them and a disposal of the debris can be made with a reasonable amount of road and transportation cost.

So far this District has not been able to work out a practical plan for removing debris from the other reservoirs which are in deep canyons high up in the mountains. As far as is known to the District, no one else has either.

Therefore, this District believes that it would be wrong to build additional storage capacity, either in large or small units, in the mountain areas. It will continue to be wrong until some practical method of maintaining such storage capacity can be worked out and adequate arrangements made for financing this maintenance.

(5) Some of the District's Reservoirs were large enough to appreciably reduce the flood peaks. Some were not. This is shown in the table below:

Dam	Peak Inflow Second Feet	Time	Peak Outflow Second Feet	Time	Reduction in Peak Second Feet	Percent Reduction
LA Pacoima	8,150	3:45 PM	2,470	2:00 AM	5,680	70
LA Tujunga	34,000	4:55 PM	32,520	5:20 PM	1,480	4
LA Devil's Gate	11,400	2:50 PM	7,060	6:00 PM	4,340	38
Sierra Madre	53,350 700	4:30 PM	688	4:30 PM	12	2
Santa Anita	4,600	4:10 PM	4,500	4:20 PM	100	2
Sawpit	1,120	4:15 PM	680	6:00 PM	440	39
Eaton	2,225	4:35 PM	2,190	4:50 PM	35	1
San Gabriel #1	94,380	4:00 PM	57,150	7:15 PM	37,230	40
San Gabriel #2	23,800	4:15 PM	22,180	4:30 PM	1,620	7
Big Dalton	1,300	3:15 PM	726	6:00 PM	574	44
San Dimas	4,400	5:10 PM	4,278	5:15 PM	122	3
Live Oak	355	2:45 PM	200	4:30 PM	155	44
Thompson Creek	600	2:30 PM	122	12:30 PM	600*	100
Puddingstone	5,850	4:40 PM	None	- - - -	5,850*	100

*No outflow on March 2nd, Release made after storm flow had stopped from area below dam.

DEBRIS BASINS.

The 16 debris basins functioned all right. They caught and retained about 700,000 cubic yards of material.

Without the basins, this volume would have gone into the channels, probably plugged them and spread out over and damaged adjacent areas.

None of the basins were overtopped.

However, the basin at Pickens was completely filled. If the storm had continued much longer, it would have been overtopped.

The temporary timber inlet at Las Flores Basin was badly damaged by moving boulders.

A concrete diversion wall at Brand Basin was partially undermined.

Damage to other basins was limited to trash guards and dewatering siphons.

It is fundamental that debris basins must be built to a certain capacity. They will not handle more than that capacity. If more material is washed into them than they can hold, the excess will top them and cause damage.

The obvious remedy is to make them big enough to hold whatever comes into them. This District is quite cognizant of this fact. It is not financially possible at this time, however, to provide any basins at all - large or small - on many channels where they are urgently needed.

Therefore, the obvious remedy for the condition pointed out above, cannot be applied until there is much more money in sight than there is now.

April 22, 1938.

CHANNELS.

(1) There was practically no damage to any of the 144,881 lineal feet of completed open concrete channels.

This is true as to those built by the United States District Engineer, as well as to those built by this District.

None of the newer channels were filled to capacity.

A portion of an old section of the Rubio Wash Channel through the San Gabriel Country Club was overtopped. However, the structure was not damaged.

A hundred foot section of the lower end of the District built Verdugo Channel was wrecked when the Los Angeles River levee at that point failed.

The covered section of the Santa Monica Channel plugged with debris. It was necessary to remove the cover in order to clean it quickly.

The way the open concrete channels functioned in general during the recent storm, shows them to be satisfactory flood control structures. ✓

(2) This District had a total of about 196,000 lineal feet of heavy rock riprap on the lower reaches of the Rio Hondo, San Gabriel and Los Angeles Rivers.

There was lost a total of 1,440 lineal feet of it at various places. These failures were due to the fact that since the placing of the riprap, the river bed had eroded below the toe rock so that the riprap failed by underscour. ✓

Lack of maintenance funds in the past prevented this District from providing additional toe rock to meet the above condition, of which it was well aware.

The experience of the last storm indicates that the above type of protection is satisfactory for the lower reaches of our streams where velocities are relatively slow.

(Channels - continued)

(3) At the beginning of the March storm, this District had in place a total of 668,654 lineal feet of pipe and wire protection of all kinds - old and new, Most of it was quite old.

There was destroyed a total of 221,170 lineal feet, or 33% of it.

There was damaged a total of 44,748 lineal feet, or 7% more.

The parts that failed, as well as the parts that stood, were and are temporary in character.

It is believed this type of protection served a useful purpose and justified its installation.

It fails quickly on sharp curves and when overtopped. It fails quickly when the bottom of the channel scours from beneath it. It stands up quite well on straight reaches and easy curves, when not overtopped.

Until something better is developed, this District proposes to keep using it for temporary protection.

(4) This District had 241,850 lineal feet of pile and wire bank and levee protection on the 1st of March, 1938.

The flood destroyed 29%, or 70,116 lineal feet and damaged 8,587 lineal feet, or 3% more of it.

About 9/10ths of the destroyed portion was very old and built of uncreosoted piles.

It is believed it served its purpose as a temporary protection.

It will stand quite a bit more than the pipe and wire protection, but fails quickly when underscoured and is not adapted for use on sharp curves.

This District expects to continue its use, when funds are not available for a more permanent and effective type of protection.

(Channels - continued)

(5) About 31% of the 100,950 lineal feet of gunite levee protection was destroyed, or a total of 31,167 feet, and 13,957 lineal feet, or 14% more was damaged.

A part of the footage lost was because of the lack of toe protection due to the scour of the river bed after placement.

As in the case of the heavy rock riprap, District funds in the past were not sufficient for proper maintenance.

The gunite also failed from various other defects.

It proved entirely unsuited to resist fast water on sharp curves.

This District does not intend to place any more new gunite protection. It does intend to repair isolated breaks in otherwise uninjured reaches. ✓

(6) The rock and wire mattress protection, of which there was a total of 101,550 lineal feet, was in general, placed on levees and banks where the velocities were high and debris conditions severe.

It held up in an outstanding manner.

At the mouth of San Gabriel Canyon it took the beating of the whole river hitting it at an angle.

It was overtopped about 6 inches but remained intact at that place.

By doing so, it probably saved Azusa and Baldwin Park from a serious inundation.

There was lost a total of 13,279 lineal feet, or 13%. There was damaged 5,300 lineal feet, or 5% more.

Practically all loss and damage was due to overtopping. Very little was due to underscour or other causes.

This District believes it a valuable, although rather expensive protection, for banks and levees against high velocities and heavy debris flows.

(Channels - continued)

(7) There were 9,000 lineal feet of rubble masonry walls prior to the flood.

There were destroyed 2,000 lineal feet, 22%, and another 1,050 feet, 12%, damaged.

The damage was caused by overtopping and underscour.

(8) There was a total of 3,500 lineal feet of plain woven wire levee facing. This was placed as an experiment. Where velocities were low, it stood up. Where they were high, it went out. About 1/3 of it was destroyed.

(9) A total of about 600 lineal feet of reinforced asphalt levee and bank protection had been placed as an experiment about one year ago.

It was built at points of direct attack by high velocities.

None of it was destroyed and only 1% showed appreciable damage.

These results are considered to warrant further use of this type of protection.

(10) This District had 94,593 lineal feet of unprotected earth and sand levees on lower San Gabriel River and Coyote Creek.

They were in the reaches where there were low velocities.

There was destroyed a total of 4,215 lineal feet, or about 4%, and 904 lineal feet require repairs, or 1% more.

Three of the major breaks are believed to be due to holes made by burrowing animals.

(Channels - continued)

(11) This District had accepted a total of 50,218 lineal feet of hand placed rock levee protection from the United States Engineer Department.

This work was on the lower reaches of Los Angeles River, Ballona Creek and Compton Creek, where there were low velocities.

None was destroyed.

About 4% was damaged to the extent of needing repairs.

It is believed that this type of protection is adequate to stand low velocities on good alignment.

Experience on Los Angeles River, above Dayton Avenue, where velocities were high and alignment crooked, shows that it is not adapted for those conditions.

This District had not accepted any of this work above Dayton Avenue.

COMMUNICATION SYSTEM.

Serious interruptions occurred in the District's telephone service in the mountain areas.

Lines between the general office and several dams were down during the storm.

The District's radio system functioned well. It completely justified its installation.

The failure of the telephone system and the success of the radio system show that radio facilities should be installed at all mountain dams.

The operation activities of this District were severely hampered by false and misleading announcements issued from some commercial broadcasting stations.

(Continued)

(1) The incident had occurred at about 10:15 P.M. and the victim had been in the area for some time.

This was the first of the series of the incident and the victim was not injured.

There was damage.

There was damage to the extent of the incident.

It is believed that the victim was not injured and the incident was not serious.

The incident was not serious and the victim was not injured. The incident was not serious and the victim was not injured.

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CONCLUSION

There is no doubt that the incident was not serious and the victim was not injured.

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Honorable Board of Supervisors

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April 22, 1938.

The foregoing complies with your order to report on the operation of Flood Control structures during the recent storm.

In addition, I wish to state that the employees of this District performed their duties well.

I take this occasion to express my thanks to them.

Yours truly,

C. H. Howell,
Chief Engineer.

CHH:hmp

cc Miss Beatty (2)

Supervisor Jessup

Legg

McDonough

L M Ford

J. A Ford

Mr. Dowds

Mr. McFadden

Mr. Prichard

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

H. H. BENNETT, CHIEF.

Harry E. Reddick,
Regional Conservator.

Southern California
Special Report on Flood of March 2, 1938
with
Some Analysis of Its Effects on Soil Conservation Projects
Located Within The Area Of
Intense Rainfall

By

TECHNICAL STAFF

REGION 10

Under Supervision of Charles W. Petit
Associate Regional Conservator

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
R. E. BENNETT, CHIEF

Harry H. Hobbins,
Regional Conservationist

Some analysis of the effects on soil conservation projects
located within the area of
Intense rainfall
Southern California
Special Report on Flood of March 2, 1938
with

By

TECHNICAL STAFF

IN CHARGE

Under Supervision of Charles E. Wells
Associate Regional Conservationist

Southern California - Flood Control Report

March 2, 1938

The appendix to this report contain data collected for the Special Flood Control Report of southern California streams for the storm of March 2, 1938, and submitted by Flood Control Field Co-ordinating Committees 18 & 20.

The subjects covered in the appendix are:

1. The Storm
2. Flood Photographs
3. Hydraulic Data
4. Erosion
5. Flood Damages

All of these data were gathered by field parties immediately following the storm and covered a period of about two weeks. Further field work would be necessary to check all data; nevertheless, they give an adequate picture of the storm and the resulting damage.

Southern California - Field Control Report

March 2, 1938

The results of this report contain data collected for the Special Field Control Report of Southern California stream for the stream of March 2, 1938, and submitted by Field Control Field Co-ordinating Committee in a 20.

The material covered in the summary is:

1. The stream
2. Field photographs
3. Streamline data
4. Stream
5. Field images

All of these data were gathered by field parties during the following the stream and covered a period of about two weeks. Further, field work would be necessary to check all data, nevertheless, they give an adequate picture of the stream and the resulting damage.

SOUTHERN CALIFORNIA FLOOD OF MARCH, 1933

AGRICULTURAL LAND DAMAGES

From time to time, in any given locality, there occurs a storm which ranks in popular terminology as a "big storm." Such storms occur at varying intervals, but in the southern California area, centering about Los Angeles, they have occurred eight times since 1862, or at an average interval of about 10 years. It is against the peak conditions of such storms that we must judge the effectiveness and sufficiency of soil conservation practices. Such peak conditions not only constitute a test of stability but, also, serve to establish design factors enabling technicians to meet expected requirements without excess investment.

It is the purpose of this report to describe the "big storm," which occurred from February 27 to March 3, 1933, over southern California, and to record as well as possible, in a brief summary, the effect upon agricultural lands with respect to soil erosion. Particular reference will be made to land lying within Soil Conservation Service project and camp areas because but little reliable data are available covering other areas. This report is compiled from detailed reports made by Flood Control Field Coordinating Committees 18 & 20, and submitted under date of March 29, 1933, by Messrs. E. I. Kotok and Harry E. Reddick, Co-Chairmen, and from a report on erosion damage on the southern California soil conservation project areas prepared under the direction of Mr. J. C. Bamesberger, Regional Engineer.

AGRICULTURAL LAND DAMAGES

From time to time, in any given locality, there occurs a storm which results in popular terminology as a "big storm." Such storms occur at varying intervals, but in the southern California area, centering about Los Angeles, they have occurred eight times since 1880, or at an average interval of about 10 years. It is against the past conditions of such storms that we must judge the effectiveness and efficiency of soil conservation practices. Such past conditions not only constitute a test of stability but, also, serve to establish design features enabling engineers to meet expected requirements without excess investment.

It is the purpose of this report to describe the "big storm" which occurred from February 27 to March 2, 1935, over southern California, and to record as well as possible, in a factual manner, the effect upon agricultural lands with respect to soil erosion. Particular reference will be made to land lying within Soil Conservation Service project and camp areas because but little reliable data are available covering other areas. This report is compiled from detailed reports made by Flood Control Field Coordinating Committees in 1935, and submitted under date of March 29, 1935, by Messrs. R. I. Leach and Harry H. Hedrick, Co-Chairmen, and from a report on erosion damage on the southern California soil conservation project areas prepared under the direction of Mr. J. C. Benschberger, Regional Engineer.

THE STORM OF MARCH - 1938 - IN GENERAL

The general flood damage and loss caused by the storm of February 27 to March 3, 1938, far surpassed those of any previous flood of record. Details as to the character of the storm and the amount of damage caused are provided in an appendix, but for introductory purposes the important facts and figures are briefly summarized in the following paragraphs:

Duration

The storm as a whole in southern California developed two distinct phases separated by a period of about ten hours during which practically no rain fell, but during which but little opportunity was given for relief by runoff or infiltration. The first period began at about 1:00 A.M., February 27 and ended 1:30 A.M., March 1. The second and more intense period began at 11:00 P.M., March 1, and lasted until 8:30 A.M., March 3. The total elapsed period was about 103 hours, and allowing for the ten hour interruption, the total net period of rainfall was about 90 hours.

Extent

The main storm, as it affected the Los Angeles area, covered all or portions of five counties; namely, Ventura, Los Angeles, San Bernardino, Orange, and Riverside, and included an area extending roughly 120 miles east and west and 60 miles north and south. The greatest precipitation occurred in the Angeles and San Bernardino National Forest areas, and severe but secondary precipitation oc-

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THE STORM OF MARCH 1935 - IN GENERAL

The general flood stage and loss caused by the storm of February 25 to March 2, 1935, far surpassed those of any previous flood of record. Details as to the character of the storm and the amount of damage caused are provided in an appendix, but for information purposes the important facts and figures are briefly summarized in the following paragraphs:

Duration

The storm as a whole in southern California developed two distinct phases separated by a period of about ten hours during which practically no rain fell, but during which the 1200 ft. family was given for relief by rainfall or infiltration. The first period began at about 1:00 A.M., February 25 and ended 1:00 A.M., March 1. The second and more intense period began at 11:00 P.M., March 1, and lasted until 8:30 A.M., March 2. The total elapsed period was about 105 hours, and allowing for the ten hour interval, the total wet period of rainfall was about 95 hours.

Intensity

The main storm, as it affected the Los Angeles area, covered all or portions of five counties: namely, Ventura, Los Angeles, San Bernardino, Orange, and Riverside, and included an area extending roughly 100 miles east and west and 50 miles north and south. The greatest precipitation occurred in the Angeles and San Bernardino National Forest areas, and severe but occasionally precipitation oc-

curred over the foothill area lying south of these mountains along the northern edge of the Los Angeles Basin.

Total Precipitation and Intensities

Total precipitation during the five day storm was from 5 to 10 inches in lowlands of the basin area; 10 to 20 inches in the foothills; 20 to 30 inches in the upper forest area, and over 30 inches in considerable areas along portions of the mountain ridge, particularly in the San Bernardino Mountains at the east end of the storm area.

Measured intensities were very high. On the basin floor - as at Los Angeles city - the higher recorded intensities per hour varied from 0.72" per hour over a 120 minute period to a recorded maximum of 1.32" per hour over a 30 minute period. Fullerton Airport recorded 2.00" per hour over a 10 minute period. At a representative point in the mountains, (Opids Camp - elevation 4380 ft.), the measured intensities were 1.25" in 30 minutes; 2.00" in 1 hour; 10.89" in 8 hours, and 15.06" in 2 1/2 hours.

Runoff

Peak flows of runoff from the area as a whole reached the highest ever recorded in this area. However, as might be expected, there was much variation due to the condition of vegetation, the nature of the soil, and the method of cultivation. Most runoff varied from 0.4" per hour to nearly 0.9" per hour, and the maximum in the areas was 2.01" per hour at Banning Canyon. Because of

curved over the foothill area lying south of these mountains

along the western edge of the Los Angeles Basin. The slope of

the slope of the foothills is very gentle and the vegetation

Total Precipitation and Humidity

Total precipitation during the five day storm was 1.25

to 10 inches in portions of the basin away to 20 inches in the

foothills; 20 to 30 inches in the upper forest area, and over 30

inches in considerable areas along portions of the mountain ridge.

precipitation in the San Bernardino Mountains at the east end of the

storm area.

Humidity measurements were very high. In the basin floor -

an at Los Angeles city - the highest recorded humidity was 100

percent from 0.75" per hour over a 150 minute period in a recorded

maximum of 1.25" per hour over a 30 minute period. At Los Angeles

port recorded 2.00" per hour over a 30 minute period. At a remote

remote point in the mountains (Point Camp - elevation 1000 ft.)

the recorded humidity was 1.25" in 30 minutes; 2.00" in 1 hour;

10.00" in 3 hours, and 15.00" in 4 hours.

Notes

Part of the wind from the area as a whole reached the

highest ever recorded in this area. However, as might be expected,

there was much variation due to the condition of vegetation, the

nature of the soil, and the method of observation. Most points

varied from 0.5" per hour to nearly 0.9" per hour, and the maximum

in the basin was 2.01" per hour at Landing Canyon. Because of

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burned areas and other watershed conditions, vast quantities of debris and silt were moved and on certain recently burned areas, measurements from past floods indicate a maximum silt load of 53% by volume of total runoff.

Damages

The extent of damage and the loss of life were such as to make the storm of disastrous magnitude. A survey of general flood damage was conducted cooperatively by the Soil Conservation Service, the Forest Service, the Bureau of Agricultural Engineering, and the Bureau of Agricultural Economics. The work was done immediately following the storm and completed within a period of about two weeks. This survey indicated that the storm damage amounted to \$83,000,000. 74 lives were lost and silt and debris were deposited on streets, roads, railroads, urban areas, reservoirs, and agricultural lands to the amount of 25,000,000 cubic yards. (Details of these losses in the five counties are given in tabular form in the Appendices.

SOIL CONSERVATION PROJECTS IN STORM AREA

Soil Conservation Service projects and camps lying within the main storm area were as follows:

1. The Las Posas Project in Ventura County
(includes Camp Sesis).
2. The Whittier Project near Whittier.
3. Cucamonga Camp near Uplands (attached to Whittier).
4. Camp Palos Verdes near San Pedro (attached to Whittier).

burned areas and other watershed conditions, vast quantities of debris and silt were moved and on certain recently burned areas, measurements from peak floods indicate a maximum silt load of 25% by volume of total runoff.

The extent of damage and the loss of life were such as to make the storm of disastrous magnitude. A survey of general flood damage was conducted cooperatively by the Soil Conservation Service, the Forest Service, the Bureau of Agricultural Engineering, and the Bureau of Agricultural Economics. The work was done immediately following the storm and completed within a period of about two weeks. This survey indicated that the storm damage amounted to \$15,000,000. It lives were lost and silt and debris were deposited on houses, roads, railroads, water courses, reservoirs, and agricultural lands to the amount of \$5,000,000 cubic yards. Details of these losses in the five sections are given in tabular form in the Appendix.

SOIL CONSERVATION PROJECTS IN STORM AREA

Soil Conservation Service projects and camps lying within the main storm area were as follows:

1. The Las Pintas Project in Ventura County (includes Camp Santa).
2. The Whittier Project near Whittier.
3. Guadalupe Camp near Upland (attached to Whittier).
4. Camp Pineda Verdes near San Pedro (attached to Whittier).

5. The Santa Ana Project near Santa Ana
(includes Camp El Toro).

As may be seen by reference to the hydrologic map, none of these areas are situated in the zone of maximum precipitation, and for all except Cucamonga Camp, the total precipitation for the storm was under 10 inches (about 12 inches at Cucamonga).

Consequently for these areas the storm was not abnormal, although it was sufficient to provide an excellent test of the effectiveness of erosion control measures. It is important to emphasize this statement - that the storm was not abnormal for these agricultural areas, but that its seriousness was with respect to damage from floods originating in the mountainous areas of greater rainfall.

Data Secured for Five Areas

Some observations were made during the storm, and immediately after it had moved off to the east, survey crews were assigned to obtain reliable data concerning the effect upon the project areas. Due to lack of personnel, it became necessary to select representative locations and accordingly surveys were made and data recorded for the following:

1. Las Posas Project (includes Camp Sonie)
2. Whittier (La Habra) Project
3. Cucamonga Camp
4. Palos Verdes Camp
5. Santa Ana (Aliso Creek) Project

... The Santa Ana Project (Santa Ana)
(includes Camp Elmore)
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Although it was sufficient to provide an excellent test of the ef-
fectiveness of stream control measures. It is important to em-
phasize this statement - that the storm was not abnormal for these
regions, but that the seriousness was with respect to
damage from floods originating in the mountainous areas of greater
rainfall.
... This storm was not the only one which was
... rain record for five years.
... These observations were made during the storm, and immedi-
ately after it had passed and the peak survey crews were es-
tablished to obtain reliable data concerning the effect upon the
project areas. Due to lack of personnel, it became necessary to
select representative locations and accordingly surveys were made
and data recorded for the following:
1. Las Pinos Project (includes Camp Santa Ana)
2. Whittier (La Brea) Project
(includes Camp Santa Ana)
3. Guernsey Camp
4. Santa Ana Project (includes Camp Santa Ana)
5. Santa Ana (Aliso Creek) Project
6. Camp Santa Ana (includes Camp Santa Ana)

4

Complete reports including data in detail were consolidated and presented as "Report of Survey of Erosion Damage Following Storm of March 2, 1938," prepared under direction of Mr. J. G. Bamesberger, Regional Engineer, Santa Paula. However, it will be found instructive to review these reports briefly, area by area, and to make whatever generalizations seem justified.

LAS POSAS PROJECT

The most complete study was that made of the Las Posas Project. Every portion of the area was surveyed from several viewpoints, and the final result is a mass of information of such a nature as to yield much valuable information upon careful analysis. Because of this rather complete survey, more space will be given to the Las Posas Project in this brief report than to the other areas upon which less complete reports were made.

The Las Posas Project lies approximately sixty miles north of Los Angeles, near Santa Paula, and consists of a roughly rectangular area, extending about ten miles parallel with the adjacent mountain range, and averaging about seven miles in width. The northern boundary of the project is the crest of South Mountain (elevation approximately 2000 ft.) and drainage is in general from the crest southward over the project.

Slopes and Soil

The steep slopes of the mountain (ranging up to 80%) are occupied by primary soils which are shallow and of little agricultural importance. The weathered secondary soils which occupy the intermed-

Complete reports including data is being now consolidated

and presented as "Report of Survey of Western Kansas Following
Survey of March 2, 1937," prepared under direction of Mr. J. C.
Henshaw, Regional Engineer, Santa Fe. However, it will be
found instructive to review these reports briefly, even by ones,
and to make whatever generalizations are justified.

THE TOWN PROJECT

The most complete study was that made of the town project.
Every portion of the area was surveyed from several
viewpoints, and the final result is a mass of information of great
value as to yield and valuable information upon general survey-
ing. Because of this rather complete survey, more space will be
given to the town project in this brief report than to the
other areas upon which less complete reports were made.
The town project lies approximately sixty miles north
of Las Alamos, near Santa Fe, and consists of a roughly two-
mile area, extending about ten miles parallel with the edge
of the mountain range, and averaging about seven miles in width.
The northern boundary of the project is the crest of South Mountain
(elevation approximately 1000 ft.), and drainage is in general from
the crest southward over the project.

Soils and Soil

The steep slopes of the mountain (ranging up to 80%) are oc-
cupied by primary soils which are shallow and of little agricultural
importance. The weathered secondary soils which occupy the intermed-

late slopes (ranging from 5% to 50%) are utilized chiefly for dry farming beans and hay. They are underlaid by dense clay subsoils and are highly erodible. The soils of the valley bottom lands are deep and permeable and are used for orchards and beans under irrigation.

Land Use and Land Values

About 19% of the total area is either in native cover (brush) or bare from the fire of October, 1937, about 39% is clean cultivated, about 25% is in hay or pasture, and the remaining 17% is in walnuts and citrus. Land values range from \$200 per acre for dry farmed land up to \$2000 for mature citrus orchards.

Precipitation and Intensity

The total precipitation during the storm (which lasted about 60 hours in the Las Posas area) was 7.26 inches, bringing the total for the season up to 21.7 which is 10.00 inches over normal for this date. The average annual rainfall over a 15 year period is 13.8 inches. The maximum intensity of this storm varied from .39 inch per hour over 4 hours up to .86 inch per hour over a 30 minutes, and peaked at 2.00 inches per hour for 3 minutes.

The Earlier Storm of February 11

The problem of determining the effect of this storm on the Las Posas area is complicated by the fact that on February 11, only about two weeks previously, there had been a storm of greater intensity than this, although of less duration. During the earlier storm,

into slopes (ranging from 15 to 25%) are utilized chiefly for dry farming beans and hops. They are underlain by dense clay subsoils and are highly erodible. The soils of the valley bottom lands are deep and permeable and are used for cereals and beans under irrigation.

Land Use and Land Values

About 15% of the total area is either in native cover (brush) or bare from the fire of October, 1937, about 15% is also cultivated. About 25% is in hay or pasture, and the remaining 15% is in wheat and alfalfa. Land values range from \$200 per acre for dry farmed land up to \$2000 for native olive orchards.

Irrigation and Infiltration

The total precipitation during the storm (which lasted about 60 hours in the Los Angeles area) was 7.15 inches, bringing the total for the season up to 21.7 inches in 1940. Inches over normal for this date. The average annual rainfall over a 15 year period is 15.5 inches. The maximum intensity of this storm varied from .75 inch per hour over 1 hour up to .85 inch per hour over a 30 minutes, and peaked at 2.00 inches per hour for 5 minutes.

The Earlier Storm of February 11

The problem of determining the effect of this storm on the Los Angeles area is complicated by the fact that on February 11, only about two weeks previously, there had been a storm of greater intensity than this, although of less duration. During the earlier storm, the watershed immediately within which occupy the watershed-

intensities reached 3.2 inches per hour for 3 minutes, 1.22 inches per hour for 30 minutes and .45 inch per hour for 2 hours - the highest ever observed on the project. The total precipitation was only 1.32 inches for this earlier storm - which was spotty - but the ground was wet from still earlier rains, causing runoff at the highest rate ever observed on the project.

Runoff

The ground was saturated from the earlier rains described above and the storm of March 2, to which discussion now reverts, was long in duration so that even though intensities of precipitation and runoff were far below previous records, the total volume of runoff was great. Substantial quantities of water and soil were discharged into the barrancas for more than 30 hours and the entire watershed acted as a unit in contributing runoff and soil.

Erosion Damage, Extent of

For practical reasons, it was impossible to segregate erosion damage caused by the storm of March 2 from that caused by the earlier storm of February 11. Consequently, the results arrived at represent the combined effect of the two storms. Direct measurements were made by our own project personnel using a straight edge, stream gauging, and other approved methods of direct measurement, in addition to general observation. Similar data are also available from other projects, but not in as complete form, nor on exactly the same basis as to storm intensities, etc.

Information received 5.2 inches per hour for 5 minutes, 1.35 inches per hour for 30 minutes and 1.5 inch per hour for 2 hours - the highest ever observed on the project. The total precipitation was only 1.35 inches for this earlier storm - which was spotty - but the ground was not from still earlier rains, causing runoff of the highest rate ever observed on the project.

Runoff

The ground was saturated from the earlier rains described above and the storm of March 2, to which attention was referred, was long in duration so that even though infiltration of precipitation and runoff were the factors previous records, the total volume of runoff was great. Substantial quantities of water and soil were discharged into the stream for more than 30 hours and the entire watershed acted as a unit in contributing runoff and soil.

Project Summary, extent of

For practical reasons, it was impossible to measure stream damage caused by the storm of March 2 from that caused by the earlier storm of February 11. Consequently, the results arrived at represent the combined effect of the two storms. Direct measurements were made by our own project personnel using a straight edge, stream gauging, and other approved methods of direct measurement, in addition to general observation. Similar data are also available from other projects but not in as complete form, nor on exactly the same basis as to stream information, etc.

SHEET EROSION

A very complete study was made of the effect of various factors on the amount of sheet erosion caused by the storm, and the simplest way to present this information in convenient form for general use is to tabulate it and relate only two variables at a time, as for example - "crops vs. erosion," "slope vs. erosion," etc. Three or four variable comparisons would be more reliable, but are not practical in a brief statement such as is required for this report. For any purpose, except a general survey of the results, reference should be made to the Project Report. The average soil loss for the entire project area was .70" over the entire 39,478 acres.

(A) Soil losses as related to slope are as follows:

Where soil loss was zero	-	average slope was 0% - 6%
" " " " " 0" to $\frac{1}{4}$ "	"	" " " 7% - 14%
" " " " " $\frac{1}{4}$ " - $\frac{1}{2}$ "	"	" " " 15% - 19%
" " " " " $\frac{1}{2}$ " - 1"	"	" " " 19% - 21%
" " " " " 1" - 2"	"	" " " 22% - 32%
" " " " " 2" - or over	"	" " " 33% - and over

NOTE: The tabulations which follow are of interest and of some significance, but it is clear that the relationships shown must be considered in connection with slope, and should not be given undue importance as independent relationships.

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(B) Soil losses as related to soil type are as follows:

<u>Type of Soil</u>	<u>Total Acres</u>	<u>Average Loss in Inches</u>
Deep Soil Light	4356	.32
" " Medium	3191	.40
" " Heavy	1409	.20
Subsoil Light	3213	.60
" " Medium	6572	.75
" " Heavy	1126	.90
Primary Soil Light	2053	.75
" " Medium	8329	1.15
" " Heavy	319	1.45

(C) Soil losses as related to crops are as follows:

<u>Nature of Crop</u>	<u>Total Acres</u>	<u>Average Loss in Inches</u>
Bare	15560	1.15
Brush	7143	1.10
Misc.	506	.85
Pasture	1360	.60
Hay	5162	.47
Walnuts	3847	.27
Citrus	2795	.13

(D) Soil losses as related to type of cover are as follows:

<u>Soil Condition</u>	<u>Total Acres</u>	<u>Average Loss in Inches</u>
Early Cover	15130	.45
Smooth Culture	7922	.63
Deep Culture	10603	.90
Late Cover	1431	1.03
Smooth	4337	1.70

(B) Soil losses as related to soil type are as follows:

Type of Soil	Soil Losses	Percent Loss in Inches
Very Soft	1.00	30
" "	0.50	10
" "	1.00	20
Soft	0.75	40
" "	0.50	75
" "	1.00	30
Primary Soil	0.50	75
" "	0.50	1.50
" "	1.00	1.50

(C) Soil losses as related to area are as follows:

Area of Crop	Soil Losses	Percent Loss in Inches
Wheat	1.00	1.50
Barley	0.75	1.50
Alfalfa	0.50	30
Peas	1.00	40
Hay	0.50	1.50
Wheat	0.50	75
Alfalfa	0.50	1.50

(D) Soil losses as related to type of cover are as follows:

Soil Condition	Soil Losses	Percent Loss in Inches
Very Good	1.00	1.50
Good	0.75	40
Very Good	1.00	30
Very Good	1.00	1.50
Good	1.00	1.50

(B) Soil losses as related to type of treatment are as follows:

<u>Type of Cultivation</u>	<u>Total Acres</u>	<u>Average Loss in Inches</u>
Miscellaneous	601	1.35
Recently Cultivated	15129	1.00
Volunteer Cover	5019	.83
Native Cover (Brush)	7019	.85
Bare of Cover	1975	.75
Grain	1477	.55
Terraced	662	.35
Basin Listed	363	.30
Cover Crop	3098	.15

SUMMARY ON SOIL EROSION

It is the conclusion of the project technicians who made the survey and organized the data that -

"Since so much of the tabular information presented points to the efficiency of vegetative cover and supplemental mechanical controls in reducing soil losses, extension of these aids to areas at present uncontrolled should do much to reduce the extremely heavy soil losses indicated by this report.

"Most effective of the various types of treatment was cover cropping. Areas protected by such crops lost only one-fifth as much soil per acre as the average for the entire project.

"Terraced areas lost only one-third as much soil per acre as the average for the entire project.

"The value of orchard cultural practices stands out clearly. Orchards lost only one-third as much soil per acre as the average for the entire project."

(2) Soil losses as related to type of treatment are as follows:

Type of Disturbance	Total Acres	Average Loss in Inches
Non-disturbance	600	1.35
Locally Disturbed	1400	1.00
Voluntary Cover	700	.80
Native Cover (Brush)	700	.80
Barb of Cover	700	.75
Grass	1400	.75
Timberland	400	.60
Barb Lined	400	.60
Barb Crop	700	.45

Summary of Soil Losses

It is the conclusion of the project technicians that the survey and analysis of the data show -

"There is much of the higher erosion potential points to the efficiency of vegetation cover and supplemental mechanical controls in reducing soil losses, extension of these aids to areas at present considered should be made to reduce the average heavy soil losses indicated by this report."

"The objective of the various types of treatment was cover existing. Areas protected by such crops have only one-third as much soil loss as the average for the entire project."

"Treated areas have only one-third as much soil loss as the average for the entire project."

"The value of natural erosion protection stands out clearly. Treated areas have only one-third as much soil loss as the average for the entire project."

NEW GULLIES FORMED BY STORM

All new channels with an average cross section of over one square foot are classified as new gullies. The number reported was 718 with an average length of 189 feet, aggregating a total length of 135,000 lineal feet, and representing a total soil loss of about 510,000 cubic feet. From these figures, the average cross section of new gullies was about ^{4.00}400 square feet. It is clear that the most important factor favoring the formation of new gullies is the type and condition of surface treatment at the time of storm, since 75% of all soil lost by gullying during this storm was in recently cultivated and comparatively bare land.

Other variables affecting the size and extent of new gullies on the project, include type of soil, type and condition of cover, slope, and previous erosion. But since analysis of these factors shows very uncertain correlation with the formation and magnitude of new gullies no data are presented. It is the conclusion of the technicians who prepared the project report that probably the most valuable control for the prevention of new gullies is the planting of clean cultivated fields to cover crops, with the use of terracing probably taking second place in importance.

DAMAGE TO BARRANCAS

There are eight main drainage channels, or barrancas in the Las Posas Project, with an aggregate length of 88,000 lineal feet, containing 89 control dam structures, which establish an average

NEW GULLIES FORMED BY STORM

All new channels with an average cross section of over one square foot are classified as new gullies. The number reported was 715 with an average length of 189 feet, aggregating a total length of 135,000 linear feet, and representing a total soil loss of about 110,000 cubic feet. From these figures, the average cross section of new gullies was about 100 square feet. It is clear that the most important factor favoring the formation of new gullies is the type and condition of surface treatment at the time of storm, since 75% of all soil lost by gullying during this storm was in recently cultivated and comparatively bare land.

Other variables affecting the size and extent of new gullies on the project, include type of soil, type and condition of cover, slope, and previous erosion. But since analysis of these factors shows very uncertain correlation with the formation and magnitude of new gullies no data are presented. It is the conclusion of the technicians who prepared the project report that probably the most valuable control for the prevention of new gullies is the planting of stream cultivated fields to cover crops, with the use of terracing probably taking second place in importance.

DAMAGE TO BARRIAGES

There are eight main drainage channels, or barrages in the Las Pinos Project, with an aggregate length of 85,000 linear feet, containing 89 control dam structures, which establish an average

grade of 1.0%. There was some silting and some lateral cutting in some cases rather severe. Approximate figures were obtained, indicating that there were about 95,000 cu. yds. of silting and about 16,300 cu. yds. of cutting.

DAMAGE BY DEPOSITION

One of the most serious aspects of this storm and of others of like magnitude, is the vast amount of material which is washed down from the upper slopes and deposited in the valley below. The deposition of silt and sand in this manner, early in the Spring, decreases seed germination with resulting lighter yields. It also causes general depreciation of the land by depositing inferior soil material, and by disturbance of cultural practices in effect at the time. Deposition in orchards, especially citrus orchards, sometimes covers the trunks of the trees to such a depth that they die.

Areas of heavy deposition usually occur at the edge of the valley floor on relatively flat fields with concentration opposite gullies or other natural drainage. In the case of the Las Vegas Project, in connection with this storm, about 400 acres were affected and upon this area there was deposited about 400,000 cu. yds. of material. This sand and silt if spread evenly, would mean 1,000 cu. yds. per acre or an average depth of 6.7 inches, although at some points the depth was 6 feet.

An interesting point in this connection is that the silt and sand which was deposited on the 400 acres was contributed by approximately 12,000 acres, indicating that each acre of deposit represented soil accumulated from about 30 acres higher up on the slope.

grade of 1.5%. There was some filling and some internal settling in some cases. Approximate figures were obtained including some items were about 25,000 cu. yds. of filling and about 15,000 cu. yds. of settling.

INTERNAL SETTLEMENT

One of the most serious aspects of this work was of course of the magnitude, in the vast amount of material which is settled from the upper slopes and deposited in the valley below. The deposition of fill and soil in this manner, only in the typical channels and particularly with settling lighter materials. It also causes general deposition of the land by depositing material only material, and by disturbance of natural processes in effect of the flow. Deposition in channels, especially where channels, some times occur the banks of the river to such a depth that they die. Areas of heavy deposition usually occur at the edge of the valley floor as indicated by the thick accumulation of deposits in other natural drainage. In the case of the low lands, deposit in connection with this stream, about 150 acres was affected and upon this area there was deposited about 150,000 cu. yds. of material. This area and still it spread evenly, would mean 1,000 cu. yds. per acre or an average depth of 0.7 inches, although at some points the depth was 1 foot.

An interesting point in this connection is that the fill and sand which was deposited on the 150 acres was consolidated by weight. Approximately 15,000 acres, including the main area of deposit represented soil consolidated from about 30 acres higher up on the slope.

Seven-eighths of the material deposited was sand, thus bearing out the statement made, that much of the material deposited is inferior soil material.

SLIPS OR LANDSLIDES

One type of destruction which is at times serious and which occurs at numerous points in the project area is the slipping of large bodies of residual soils on the shale or clay substrata. Areas as large as an acre may slip in this manner, causing a vertical displacement of 6 or 8 feet and disturbing the surface of the area which has slipped in such a manner as to make it more susceptible to sheet and gully erosion.

THE DAMAGE TO MECHANICAL CONTROLS

The heaviest damage to mechanical control occurred to two earth filled dams, but damage was not serious. The only other damage to mechanical controls in the area consisted of small wash outs and overtopping of structures. It is estimated that damage to all mechanical controls in all the area will be less than 2% of the original cost of the structures which suffered damage.

GENERAL CONCLUSIONS

No general conclusions are set forth in the project report, except the conclusion that appropriate vegetative control supplemented, if necessary, by minor mechanical controls such as terracing, basin listing, etc., is probably the most effective treatment. With such a control program, results on the Las Posas area have been highly satisfactory, land thus protected having lost only one-seventh as much

several-edges of the material deposited and found, that bearing
out the statement made, that much of the material deposited is
inferior soil material.

REPORT OF INVESTIGATION

One type of contamination which is of three sections and which
occurs at numerous points in the project area is the filling of
large holes of residual soils on the sites of clay substrata.
Areas on large as on some very clay in this manner, causing a water-
oil displacement of 4 or 5 feet and disturbing the surface of the
area which has slipped in such a manner as to make it more easily
slide in short and long sections.

THE HAZARD TO MECHANICAL CONTROLS

The greatest danger to mechanical controls occurred in the
earth filled area, but danger was not serious. The only other
danger to mechanical controls in the area consisted of small work
outs and overtopping of structures. It is estimated that damage
to all mechanical controls in all the area will be less than 5% of
the original cost of the structures which suffered damage.

GENERAL CONCLUSIONS

In general conditions and with the project report,
though the conclusion that appropriate vegetation control might
be needed, it is necessary, by which mechanical controls such as
locks lifting, etc., is probably the most effective treatment. With
such a control program, results on the low level area have been high
and satisfactory, and that protected landing has only one-seventh as much

soil in this stream in this area as bare cultivated land.

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THE SANTA ANA (ALISO CREEK) PROJECT

The Santa Ana Project consists of an irregular area about fifteen miles long and three miles in average width, extending in a northwesterly and southeasterly direction with its upper end located about five miles east of the City of Santa Ana. It contains about 23,400 acres and has one camp attached to the project and working adjacent to the project area.

Slopes and Soil

The central part of the area consists of moderate to steep sloping hills, having a soil which is predominantly light to medium residual. These soils are farmed principally for beans, and both are by nature and culture very susceptible to erosion.

In the southern and eastern part, the hilly lands merge into gently sloping bench land having old secondary soils underlaid by dense clay subsoil. This land is used for grain and is easily erodible. To the north and west, the hills drop more abruptly to the fans and bottom lands which are of deep permeable soil used for citrus and beans, thus being exposed and easily erodible.

Land Use and Land Values

About 80% of the land is under cultivation, viz., 37% to citrus, 21% to beans, and 19% to grain, truck crops and walnuts. Land values range from \$250 to \$750 per acre for grain and bean land, and

well in this town in this area as for cultivated land.

THE BANDA AREA (ALSO COVERED) PROJECT

The Banda and Project consists of an irregular area about 25,000 acres and three miles in average width, extending in a northwesterly and southeasterly direction with the river and is situated about five miles east of the City of Banda. It contains about 25,000 acres and has one crop attached to the project and is situated adjacent to the project area.

General and Soil

The central part of the area consists of moderate to steep sloping hills, having a soil which is predominantly light to medium weight. These soils are formed principally by basalt and tuff and by nature and culture very susceptible to erosion. In the southern and eastern parts, the hills have more level gently sloping areas having old secondary soils underlain by heavy clay basalt. This land is used for grain and is easily eroded. In the north and west, the hills have more directly to the east and bottom lands which are of very poor quality and used for dry crops and pasture. These areas are exposed and easily eroded.

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Land use and land management
about 50% of the land is under cultivation, viz., 30% to 40% rice, 10% to 20% sugar, 10% to 20% banana and coconut, and 10% to 20% other crops. The land is used for grain and for pasture and for other purposes.

up to \$2500 per acre for citrus or avocado land. The pasture, brush, and woodland of the hills are of little value.

Precipitation and Intensity

Previous storms of the winter had accumulated 8.1 inches of precipitation well distributed and the storm of March 2 had 7.92 inches of rain, half of which fell in the last twenty hours, on soil already saturated. The maximum intensity for a short period was 1.50 inches per hour over ten minutes. In expectation of but little additional rainfall this spring, farmers of clean cultivated crop land had harrowed most of the fields to conserve moisture, leaving the ground in its most susceptible condition for erosion. Most of the damage evident after the storm of March 2 was, therefore, due to that storm and reflected only slight damage done by previous storms.

This was not in any way an abnormal storm for this area from the standpoint of the agricultural land, and damage by erosion was not greater than previously observed. There was no flooding on the project and deposition was confined to a few small areas with almost negligible injury. Hence, no effort was made to obtain a complete analysis of storm damage, and in this report only general comments can be offered.

SHEET EROSION

Total soil loss averaged over the entire 23,000 acres, was about 27 cu. yds. per acre, which means an average over the total area of about .13 in depth. No loss occurred on 46% of the area,

up to \$1000 per acre for silver or succinic acid. The potassium, bromine, and manganate of the hills are of little value.

Geological and Mineralogical

Previous studies of the region had demonstrated that layers of investigation were distributed and the extent of them was 1.5 to 2.0 miles of water, half of which fell in the last twenty years, on soil already saturated. The maximum intensity for a short period was 1.50 inches per hour over the mountain. In comparison of the little additional rainfall this year, amounts of about equivalent crop land had returned most of the hills in concrete material, leaving the ground in the most susceptible condition for erosion. Most of the damage occurred after the storm of March 2 was, however, due to that storm and reflected only slight damage done by previous storms.

This was not in any way an unusual storm for this area from the standpoint of the agricultural land, and damage by erosion was not greater than previously observed. There was no flooding on the property and investigation was confined to a few small areas with almost negligible injury. Hence, no effort was made to obtain a complete analysis of storm damage, and in this report only general comments can be offered.

STORM DAMAGE

Total soil loss averaged over the entire \$3,000 square, was about 17 cu. yds. per acre. This means an average over the total area of about .15 in depth. No loss occurred on top of the area.

from 0 to $\frac{1}{2}$ " on another $\frac{1}{4}\%$, and on only 10% of the area were the average losses greater than $\frac{1}{2}$ ". The maximum loss of over 2" occurred on only 100 acres of bean land on very steep slopes and on which there was no crop or cover.

Effect of Slope on Sheet Erosion

Because of the comparatively small losses, the data scatters too much to justify any generalization except as follows: Areas of no measurable loss are found of different soil series in all slope classifications up to C-3-21%. Losses of .50" and over occurred only in the slope classifications above 11.0% and losses of over 1.0" only on slopes of the order of C-15% and on bare or sparsely cropped areas.

Soil losses as related to type of crops are as follows:

<u>Nature of Crop</u>	<u>Total Acres</u>	<u>Average Loss in Inches</u>
Hay	5700	.55
Pasture	1700	.50
Miscellaneous	500	.50
Bare	6155	.15
Orchard	5950	.00
Native Cover	1083	.00

Effect of Soil Type on Sheet Erosion:

The data scatters so much that a tabulation would be inconclusive. As already suggested, this condition is probably due to the slight amount of erosion which was not of sufficient severity to show up potential differences.

from 0 to $\frac{1}{2}$ on another hill, and on only 1% of the area was the average loss greater than $\frac{1}{2}$. The number loss of over 2" occurred on only 1% area of bare land on very steep slopes and on which there was no crop or cover.

Effect of Soil Type on Sheet Erosion

Because of the comparatively small losses, the data concerning the work to justify any generalization except as follows: losses of no measurable loss are found at different soil series in all slope classifications up to 2-3%. Losses of .5% and over occurred only in the slope classifications above 11.5% and losses of over 1.5% only on slopes of the order of 2-11% and on bare or sparsely covered areas.

Soil losses as related to type of cover are as follows:

<u>Soil Type</u>	<u>Total Loss</u>	<u>Losses Loss in Trees</u>
1.5% - 2.5% slope	1.50	1.50
2.5% - 3.5% slope	1.50	1.50
3.5% - 4.5% slope	1.50	1.50
4.5% - 5.5% slope	1.50	1.50
5.5% - 6.5% slope	1.50	1.50
6.5% - 7.5% slope	1.50	1.50
7.5% - 8.5% slope	1.50	1.50
8.5% - 9.5% slope	1.50	1.50
9.5% - 10.5% slope	1.50	1.50
10.5% - 11.5% slope	1.50	1.50

Effect of Soil Type on Sheet Erosion

The data indicate no more than a correlation with the loss of surface, as already suggested, this correlation is probably due to the slight amount of erosion which was not of sufficient severity to show up potential differences.

Effect of Condition of Cover on Sheet Erosion

The depth of erosion was practically zero with dense cover, about .20" average for moderate cover and about .45" average for no cover.

Effect of Type of Treatment on Sheet Erosion

Practically the only acreage on which heavy erosion occurred was that on which there was no cover and no cultural or mechanical treatment, and to a slight extent on pasture.

GULLY EROSION AND DEPOSITION

There was almost no gully erosion, except that a drop in an uncontrolled section in Aliso Creek cut back 400 feet and caused a loss from the creek bed and adjoining field of 15,000 cu. yds. There was very little deposition, the volume of which is not reported.

STRUCTURES

All structures and other mechanical controls functioned as designed and there were no failures or important items of damage.

SUMMARY

The project report states as follows:

"Cover cropping on orchard land was practiced almost without exception on the project and with gratifying results. Close inspection of many orchards and measurement of silt deposits showed a maximum soil loss of .02 inch on cover cropped and winter furrowed orchards. On some of the more level orchards where cover had already

Effect of Position of Cover on Heat Transfer

The depth of cover was practically zero when cover, about 1/2" average for moderate cover and about 1 1/2" average for no cover.

Effect of Type of Treatment on Heat Transfer

Investigating the only average on which heavy erosion occurred was that on which there was no cover and no chemical or mechanical treatment, and to a slight extent on pasture.

HEAT TREATMENT AND IMPROVEMENT

There was almost no early erosion, except that a deep in an experimental section in June 1933 and June 1934 and caused a loss from the cover bed and adjoining field of 15,000 cu. yds. There was very little deposition, the volume of which is not re-

ported.

CONCLUSIONS

All structures and other mechanical controls functioned as designed and there were no failures or important loss of energy.

REMARKS

The project report number is follows:

"Cover spreading on eroded land was practiced almost without exception on the project and with gratifying results. Close inspection of any records and measurement of all deposits showed a maximum soil loss of 0.3 inch on cover spread and when treated eroded. On some of the same level eroded where cover had already

been discsed loss was about twice this figure. Prevalent plantings were of vetch, oats, mustard, sweet and bur clover, malva, and barley, or combinations.

"Comparisons show the inadequacy of terraces without contour cultivation even on the lower slopes and their insufficiency on the steeper slopes without either contour subsoiling or cover crop as a supplementary measure. Consistent tendency for rilling to start immediately below each terrace on fields which were not so treated reveals the inability of terraces alone, regardless of spacing, to solve the problem.

"The value of basin listing, block furrowing and contour furrowing in eliminating runoff as well as soil loss is apparent by comparison with surrounding smooth cultivated fields. Improved cultural practices, vegetative cover, and terracing in combination with these two has decidedly reduced the sheet erosion on the project."

THE WHITTIER (LA HABRA) PROJECT

The Whittier Project consists of a roughly rectangular area about six miles wide from north to south; and extending about ten miles from east to west with its western edge almost touching the city of Whittier. It has two camps attached, one inactive (Palos Verdes) and one active (Cucamonga), both off the project area. The project contains about 32,000 acres.

been checked into two other cases this figure. Previous findings
none of which, except, except, except, except, except, and
except, or conditions.

"Experiments show the tendency of persons without control
disturbances even on the lower steps and their instability on the
steep slopes without other control, especially in cases of a
complexity measure. Consistent tendency for falling to occur in-
voluntarily before each person on fields which were not as treated re-
sults the inability of persons when, regardless of speaking, to
solve the problem.

"The value of basic testing, which is usually and which is
usually in obtaining results as well as well as is dependent by con-
dition with surrounding events and related fields. Improved material
positions, vegetative cover, and increasing in combination with these
two has definitely reduced the effect of the project."

THE WHISTLE (LA BARRA) PROJECT

The Whistle Project consists of a roughly rectangular area
about six miles wide from north to south; and extending about ten
miles from east to west with the western edge almost touching the
city of Whistler. It has two camps attached, one inactive (Lance
Vernon) and one active (Lance), both off the project area. The
project contains about 25,000 acres.

Whistler is one of the most beautiful and scenic areas in the
country. It is a beautiful area with many scenic views and many
scenic views.

Slopes and Soil

The northern and central portions of the area are occupied by the Puente Hills with slopes ranging from 20% to 100% and with rather shallow primary soils. The remainder of the area to the south and particularly toward the easterly and westerly ends are gently sloping benches with slopes from 3% to 5% merging into the flat lands to the south, east, and west. The soils in this portion of the area are underlaid with heavy clay subsoils.

Land Use and Land Values

About 30% of the area, consisting chiefly of the steeply sloping lands of the Puente Hills, is in native grass cover with occasional brush and woodland. About 50% of the project area is devoted to citrus, avocado and walnuts and the remaining 20% to grain, beans, and miscellaneous crops.

The small and intensively developed avocado and citrus groves are valued at from \$1000 to \$1,000 per acre, these values being partly due to houseite value. The rest of the land used for grain, etc., is valued at from \$200 to \$500 per acre.

Precipitation and Intensity

Previous to the storm of March 2, the total precipitation on the project had been 10.76 inches, and during the storm of March 2, additional precipitation totaled 9.82 inches more, thus bringing the total for the season to date up to 20.58 inches, as compared with a normal of 13.5 inches. From various observations

Soils and Topography

The northern and central portions of the area are occupied by the Pecos Hills with slopes ranging from 20% to 100% and with rather shallow gully soils. The remainder of the area to the south and particularly toward the eastern and western ends are gently sloping benches with slopes from 5% to 25% varying into the flat lands to the south, east, and west. The soils in this portion of the area are underlain with heavy clay subsoils.

Land Use and Land Values

About 25% of the area, consisting chiefly of the steeply sloping lands of the Pecos Hills, is in native grass cover with occasional brush and woodland. About 20% of the project area is devoted to alfalfa, sorghum and wheat and the remaining 55% is in grain, pasture and miscellaneous crops.

The small and intensively developed woods and alfalfa groves are valued at from \$1000 to \$2000 per acre, those values being partly due to timber value. The rest of the land used for grain, etc., is valued at from \$200 to \$500 per acre.

Precipitation and Humidity

Previous to the storm of March 2, the total precipitation on the project had been 10.75 inches, and during the storm of March 2, additional precipitation totaled 9.25 inches more, thus bringing the total for the season to date up to 20.00 inches, as compared with a normal of 15.5 inches. From various observations

and measurements, it does not appear that there were any extreme intensities in this locality during the storm of March 2.

SOIL EROSION

This was not an abnormal storm from the standpoint of erosion and as at Santa Ana, no elaborate study was made. On 47% of the area, no soil loss whatsoever was observed, and on the most severely eroded field the loss was less than .50" average. Total estimated loss was about 4.3 cu. yds. per acre or only about .035" of depth. This is so small as not to justify any attempt to tabulate the comparative sheet erosion data given in the project report.

GULLIES AND SLIDES

There was no loss from formation or extension of gullies but there were about 100 slides involving 7000 yards of soil and the loss of 300 full grown avocado trees. All these slides occurred on terraced land of over 40% slope. There was practically no deposition.

STRUCTURES

All structures, lined ditches, pipelines, and terraces constructed by the Service, functioned perfectly.

CONCLUSION

The situation did not involve a sufficient loss to reveal any conclusion of sufficient significance for presentation, except that so far as can be seen, the value of vegetative cover is clear.

THE CUCAMONGA AREA

Cucamonga Camp is situated just north of Uplands, about 40 miles east of the City of Los Angeles, and close against the steep and high mountain range which bounds the Los Angeles Basin on the north. The total area which can be served by the camp includes 96 square miles and the area upon which the camp has worked covers 12 square miles. Detailed surveys were made only on the 12 square miles on which work had been done.

Slopes and Soils

The main portion of the camp work area is on the better land not subjected to hazard by runoff from larger watersheds. Flood waters passing through, and those running off the area itself, are handled by ditches and revetments, and diverted into storm outlet channels.

Most of this camp work area is on "A" and "B" slopes, and constitutes the major portion of about 11,500 acres which is planted to citrus and deciduous fruits. The greater portion of this land had good cover crops at the time of the storm. Outside of the camp work area is to be found the poorer land of which about 10,800 acres are in grapes, 4,000 acres in hay and 15,700 acres in brush.

Precipitation and Intensity

Four rain gauging stations in the area showed an average precipitation for the storm of 7.39 inches - which brought the total for

THE COLUMBIAN RIVER

Columbia River is situated just north of Upland, about 10 miles east of the City of Los Angeles, and rises against the steep and high mountain range which bounds the Los Angeles Basin on the north. The total area which can be served by the river is about 10 square miles and the area upon which the river has settled covers 10 square miles. Detailed surveys were made only on the 10 square miles on which work had been done.

History and Geology

The main portion of the river work area is on the bottom land not subjected to erosion by small river water courses. Flood waters passing through, and those running off the river itself, are handled by ditches and waterways, and diverted into other outlets. Most of this river work area is on "A" and "B" slopes, and constitutes the major portion of about 11,500 acres which is planned to irrigate and develop further. The greater portion of this land had good cover crops at the time of the survey. Outside of the camp work area is to be found the greater part of which about 10,000 acres are in grass, 10,000 acres in hay and 10,000 acres in brush.

Vegetation and Land Use

Four main groups of plants in the area showed an average production for the year of 7.53 inches - which brought the total for the year of 10.00 inches. The greater portion of the area is in grass, 10,000 acres in hay and 10,000 acres in brush.

the season to 36.00" as against a normal of 21.00". The intensities are not mentioned in the area report but are referred to in the words "because of the low intensities."

Observation on Erosion

The data presented are incomplete and not in form to justify much generalization. No data are shown relating to the effect of slope or soil type, but some are presented to show the effect of crops and condition of cover. For hay, native cover, and most of the citrus, the depth of erosion was slight, but for vineyards and some citrus, it was high and reported as 1.1". This was probably due to the fact that most of the citrus and vineyard lands referred to were without any cover; whereas, almost all the rest of the area had dense or moderate cover.

There was much damage due to flood water in the area east and outside of the camp area, where the soil is sandy and rocky. Hundreds of acres are in rocky unimproved brush covered land much of which was overwhelmed with rock and sand during the storm. Other acreages are in olives, walnuts, hay, and some citrus, with permeable soils and on these areas little or no sheet erosion occurred.

Comments on Protective Measures

Basin listing even on slopes considered too steep for effective application, reduced runoff to a marked degree. Annually, constructed grade ditches, diversion dikes, lined ditches and

the mean to 25.00° as against a normal of 22.00°. The values
which are not mentioned in the above report but are referred to
in the words "balance of the information."

Observations on the water

The data presented are incomplete and not in form to
give much generalization. No data are shown relating to the
depth of slope or soil type, but some are presented to show the
effect of crops and condition of cover. For hay, native cover,
and most of the others, the depth of erosion was slight, but for
vineyard and some others, it was high and reported as 1.1".
This was probably due to the fact that most of the others and
vineyard lands referred to were without any cover; whereas, almost
all the rest of the area had heavy or moderate cover.
There was much change in the flood water in the area and
and outside of the up area, where the soil is mostly sand and
loam of some sort is mostly unimproved fresh covered land with
of which was associated with rock and sand during the storm.
Other examples are in olive, walnut, fig, and some others, with
possible soils and on other areas little or no cover was shown
with.

Remarks on the water

There is little or no slope mentioned too steep for
positive application, except that in a noted degree. Anomalous
conditions such as those, however, have been noted.

-2-

broadbase terraces all functioned perfectly in protecting land covered by cooperative agreement, and in some cases adjacent lands. Letters are presented expressing very favorable comments from farmers.

THE PALOS VERDES AREA

Palos Verdes Camp work area which contains about 15,000 acres is roughly circular in form, about five miles in diameter and lies to the west of San Pedro, between the City of Los Angeles and the Pacific Ocean, at the southwestern extremity of the San Pedro Peninsula. About 5,400 acres have been worked on by the camp, which is located in the north central portion of the area near the City of Wilmington.

Soil and Slopes

The slope range is from 3% to 75%, and the better agricultural lands are found on prominent step-like terraces averaging from 5% to 15% in slope. The soil is of the heavy to medium texture residual type which is relatively permeable and highly susceptible to erosion, thus making terracing particularly adaptable as an erosion control practice.

Precipitation and Intensity

Data on precipitation as given in the project report are not conclusive, but it appears that total precipitation previous to this storm had been only about 11.18" for the winter. The storm added 6.20", but intensities were not abnormal.

proceeds towards all mentioned property in preceding land
covered by cooperative agreement, and in some cases adjacent
lands. Letters are presented expressing very favorable comments
from farmers.

THE PALM SPRING AREA

The Palm Spring area is located in the south-western part of the San
Bernardino County, and is roughly circular in shape, about 15 miles in diameter
and lies to the west of San Bern, between the City of Los Angeles
and the Pacific Ocean, at the southern extremity of the San
Bernardino Mountains. About 15,000 acres have been watered by the canal,
which is located in the north central portion of the area near the
City of Wilmington.

Soils and Climate

The slope ranges from 25 to 75°, and the bottom slightly
level. Lands are found on gradient steep-slopes between averaging
from 25 to 75° in slope. The soil is of the heavy to medium tan-
two residual type which is relatively permeable and highly sus-
ceptible to erosion, thus making farming particularly adaptable
as an erosion control problem.

Precipitation and Humidity

Data on precipitation is given in the project report and
not conclusive, but it appears that total precipitation previous
to this year had been only about 11.5" for the winter. The same
added 6.5", but information was not obtained.

Observations on Erosion

The average depth of soil loss over the area was less than $1/16"$ so that no tabulations are justified concerning the effect of various factors on sheet erosion. As usual, maximum loss occurred on bare land on the steeper slopes but fortunately there were less than 200 acres of this. Some comments by the technicians who made the report may be of interest as summarizing the situation and they are as follows:

"Agriculture of the Palos Verdes area prior to the establishment of a Soil Conservation Project was conducted with utter disregard of slope or contour. This haphazard method of operating led to serious problems. Approximately 15 miles of terraces covering 525 acres of hay and vegetable land were established during the construction period. Observations made at the conclusion of the 1937 rainy season definitely showed this type of control to be the solution of a very serious local erosion problem.

"Following the major storm of March 2, 1938, further observations showed this control functioning in a highly satisfactory and gratifying manner. No soil losses occurred on terraced areas having a slope of 15% or less. Results obtained by the Palos Verdes broadbase terracing demonstration constitutes, for all practical purposes, complete control of this area's sheet erosion problems and comprises a revolutionary contribution to soil and moisture conservation in this southern California area."

"Close growing grain crops offered excellent protection for a major portion of the area. Four thousand, three hundred and

Observations on erosion

The average depth of soil loss over the area was less than 1/2 inch, as shown by calculations and justified assuming the effect of various factors on erosion. As usual, maximum loss occurred on bare land on the steeper slopes but fortunately there were less than 100 acres of this. Some remarks by the participants who made the report may be of interest in summarizing the situation and they are as follows:

"Agencies of the State Forest have prior to the establishment of a Soil Conservation Project was conducted with other divisions of State in cooperation. This happened in the spring of 1937 when of heavy and vegetable land were established during the summer period. Observations made at the conclusion of the 1937 rainy season definitely showed this type of erosion to be the result of a very serious local erosion problem."

"Following the rainy season of March 2, 1937, further observations showed this erosion resulting in a highly satisfactory and profitable manner. The soil losses occurred in scattered areas having a slope of 1% or more. Results obtained by the State Forest Service during demonstration conditions, for all practical purposes, indicate control of this area's erosion problem and emphasize a revolutionary contribution to soil and erosion conservation in this southern California area."

"Close growing grain crops offered excellent protection for a major portion of the area. Four thousand three hundred and

sixty-four (14,364) acres were covered by these crops which were planted in the fall and had developed extensive root systems and surface forage that served to bind the soil. Erosion losses were slight where such crops had been planted. Grain hay areas which had been terraced showed practically no soil loss."

"Clean cultivated row crops when contrasted with grain hay culture presented losses worthy of comparison as considerable soil was lost in all instances where these crops were grown without protection. Fields cropped to beans are essentially the problem areas on this project. Soil loss was conspicuous especially where cultivation was coincident with prevailing slopes. Excessive losses were minimized by inherent characteristics of the soils utilized by such crops. Such soils have a very low susceptibility to erosion and stand up well under abuse but despite this favorable factor extensive acreages were damaged. Terraced bean fields showed slight erosion losses.

"Land retired from cultivation, terraced, and sown to native pasture grasses resisted damage satisfactorily. However, this was also true of similar native areas which had no terraces. For general conservation work under similar soil, slope, and climatic conditions, it is deemed sufficient to merely remove critical areas from cultivation as grasses apparently are capable stabilizing agents."

APPENDIX II

Section 1.

STORM DESCRIPTION AND RAINFALL RECORDS

By

Wm. L. Minaker
Associate Engineer
U. S. Forest Service

APPENDIX II

Section 1

Storm of February 26 - March 3, 1938

STORM DESCRIPTION AND RAINFALL RECORDS

By

Wm. L. MINAKER
Associate Engineer
U. S. Forest Service

APPENDIX II

Section I

Storm of February 25 - March 5, 1933

STORM DESCRIPTION AND RAILROAD RECORDS

By

Wm. L. MINNER
Associate Engineer
U. S. Forest Service

STORM DESCRIPTION AND RAINFALL RECORDS

Storm of February 26 to March 3, 1938,
Southern California

Compiled by W. L. Minaker
Associate Engineer, U. S. Forest Service

(For incorporation in Special Flood Report by U. S. Department
of Agriculture)

Storm Description

During the period February 27 to March 3, 1938, two successive storms occurred in southern California. The first and lesser one started at approximately 1:00 A. M. on February 27 and ended at 1:30 A. M. March 1, while the second and more intense storm started at 11:00 P. M. March 1 and ended 8:30 A. M. March 3. Both storms came off the coast, the former carrying as far east as Texas, while the latter carried across the United States. Due to the short interval of time separating them, the two storms were combined as one in the compilation of rainfall records and drafting of the isohyetal map.

In southern California the high intensities occurred in the mountainous regions from the Topa Topa Range in Ventura County across the San Gabriel, San Bernardino and San Jacinto Ranges, and south to Palomar Mountain in San Diego County. The magnitude of the storm in their respective valleys ranged from 4 to 10 inches. Most of this mountain area received 20 inches or more of rain during the five days, and a few points received from 28 to 34 inches. Rainfall in the intermontane valleys, and in the lowlands to the desert and the coast, ranged from 4 to 10 inches.

STORM DESCRIPTION AND RAINFALL RECORDS

Storm of February 26 to March 3, 1938,
Southern California
Compiled by W. L. Miner
Associate Engineer, U. S. Forest Service

(For incorporation in Special Flood Report by U. S. Department
of Agriculture)

Storm Description

During the period February 27 to March 3, 1938, two successive storms occurred in southern California. The first and lesser one started at approximately 1:00 A. M. on February 27 and ended at 1:30 A. M. March 1, while the second and more intense storm started at 11:00 P. M. March 1 and ended 6:30 A. M. March 3. Both storms came off the coast, the former extending as far east as Texas, while the latter carried across the United States. Due to the short interval of time separating them, the two storms were combined as one in the compilation of rainfall records and drafting of the isohyetal map.

In southern California the high intensities occurred in the mountainous regions from the Topa Range in Ventura County across the San Gabriel, San Bernardino and San Jacinto Ranges, and south to Palomar Mountain in San Diego County. The magnitude of the storm in their respective valleys ranged from 4 to 10 inches. Most of this mountain area received 20 inches or more of rain during the five days, and a few points received from 28 to 34 inches. Rainfall in the intermontane valleys, and in the lowlands to the desert and the coast, ranged from 4 to 10 inches.

Associate Engineer
U. S. Forest Service

The mountains received not only the greatest volumes but also the highest rainfall intensities during this storm. Typical intensities were measured instrumentally on March 2 at two points - Opid's Camp at 4380 feet elevation in the San Gabriel Mountains, and Lake Arrowhead at 5000 feet in the San Bernardino Mountains - as follows:

1.25	inches	in	30 minutes
2.00	"	"	1 hour
10.89	"	"	8 hours
15.06	"	"	24 hours

Prior to the storm, there was very little snow below 6000 feet in elevation, while above this level snow estimates from 6 to 60 inches were recorded.

Storm data were obtained from the U. S. Weather Bureau, Los Angeles County Flood Control District, Orange County Flood Control District, and numerous power and water companies and private individuals. All figures except those given by the Weather Bureau are tentative, subject to final revision.

According to the Weather Bureau at Los Angeles, the intensity of this storm, for its five-day period, was the highest on their records, which go back to 1877.

The isohyetal map, superimposed on one of the maps accompanying the Departmental report, was prepared with the assistance of the U. S. Weather Bureau in San Francisco.

The mountain received not only the greatest volume but also the

highest rainfall intensities during this storm. Typical intensities

were measured instrumentally on March 2 at two points - Old's Camp at 1380 feet elevation in the San Gabriel Mountains, and Lake Arrowhead at

5000 feet in the San Bernardino Mountains - as follows:

1.25 inches in 30 minutes	"	"
2.00 " " 1 hour	"	"
10.89 " " 8 hours	"	"
12.00 " " 24 hours	"	"

Prior to the storm, there was very little snow below 6000 feet in

elevation, while above this level snow estimates from 6 to 60 inches were

recorded. Both above and below the snow, the storm was

Storm data were obtained from the U. S. Weather Bureau, Los Angeles

County Flood Control District, Orange County Flood Control District, and

numerous power and water companies and private individuals. All figures

except those given by the Weather Bureau are tentative, subject to final

revision. Efforts to obtain the high intensities occurred in the snow-

According to the Weather Bureau at Los Angeles, the intensity of the

this storm, for the five-day period, was the highest on their records,

which go back to 1877. The records of the storm in their possession

The facsimile map, superimposed on one of the maps accompanying the

Departmental report, was prepared with the assistance of the U. S. Weather

Bureau in San Francisco. Rainfall in the Sacramento Valley, and

in the San Joaquin Valley, was also recorded, ranging from 10 to 15 inches.

LOS ANGELES COUNTY

LOS ANGELES COUNTY

RAINFALL LOS ANGELES COUNTY

Tab. No.	Station	2/27	2/28	2/29	3/1	3/2	3/3	3/4	Total	Mar. Elev.
L-1	Barrymore Res.	1.65	1.85	1.15	1.15	1.00	1.49	2.12	2100	
L-2	Power #1-San T	1.95	1.64	1.50	3.86	3.31	8.22			
L-3	Power #2-Fernando	1.57	1.78	1.62	3.63	1.18	8.08			
L-4	Palmdale	1.44	1.87	2.39	1.14		5.57		2048	
L-5	Llano	1.27	1.47	1.75	1.45		4.52		2100	
L-6	Newhall	1.51	1.32	2.31	6.06	1.86	11.99		1245	
L-7	P. H. San Fred T	1.22	3.21	1.97	3.66	21	10.53		1750	
L-8	Lo. San Bern. H.	1.30	2.10	3.25	0.07		9.37		215	
L-9	San Fernando	0.03	1.31	1.86	3.03	1.06	8.93		1700	
L-10	Pacoima	1.88	2.01	5.39	1.27		11.48			
L-11	Tujunga	1.01	2.12	2.07	6.02	1.88	13.10		2500	
L-12	Haines Canyon	1.20	2.58	2.22	7.47	0.75	14.25		2550	
L-13	Low Haines	1.27	2.70	2.36	7.80	0.85	14.98		200	
L-14	Upper Haines	1.27	3.31	2.92	10.39	1.16	19.38		2150	
L-15	Briggs Terrace	1.18	3.34	3.17	9.98	0.86	18.53		2310	
L-16	Pickens Canyon	1.43	3.60	3.14	8.12	1.06	17.23		2000	
L-17	Big Tujunga	1.29	3.19	3.00	9.53	.22	17.23		3100	
L-18	Clear Creek	1.34	3.39	3.61	3.24	1.10	22.15		3100	
L-19	Arroyo Seco	1.26	2.62	2.62	8.10	1.00	15.60		1155	
L-20	Alhambra	1.86	2.75	2.18	8.33	0.62	15.74		1328	
L-21	Raton Dam	1.46	2.83	2.49	7.35	0.62	14.66		2000	
L-22	Henningsen Flat	1.37	3.82	2.58	8.60	91-08	19.30		2650	
L-23	Mr. Wilson	0.33	3.68	8.07	2.30	11.48	26.23	0.57	2850	
L-24	Ugida Camp	1.79	4.89	3.21	11.92	2.44	27.25		1330	
L-25	Loma Ranch	1.24	0.93	1.60	Accounted		9.25		1050	
L-26	San Gabriel	1.90	4.53	3.52	13.42	1.18	24.55		2335	
L-27	Hoeges Camp	1.71	7.82	4.06	13.95	2.54	30.08		2750	
L-28	Santa Anita B	1.30	4.06	3.53	6.76	.73	16.38		1400	
L-29	Santa Madre	1.54	4.18	2.18	7.89	0.58	16.37		1050	
L-30	Sawpit Dam	1.05	3.81	2.90	6.50	2.13	16.39		1378	
L-31	Monrovia						13.97		600	

RAINFALL

LOS ANGELES COUNTY - (cont.)

Tab.:	Station	2/27	2/28	3/1	3/2	3/3	3/4	Total	Est. Elev.
L-31:	Azusa P.H.	1.37	2.80	2.60	6.47	1.61		14.85	1000
L-32:	Glendora	accum:	3.12	3.05	5.77	1.57		13.51	800
L-33:	Big Dalton Dam	1.24	3.66	3.42	6.58	0.07		14.97	1575
L-34:	San Dimas #514							17.56	
L-35:	San Dimas R. G.							18.56	
L-36:	San Gabriel #1	0.15	2.83	5.30	1.92	8.16	0.13	18.49	1700
L-37:	San Gab. #1 Camp	1.43	3.75	3.12	12.52	1.17		21.99	1700
L-38:	San Dimas	1.14	2.22	2.90	7.18	1.24		14.68	1350
L-38:	San Dimas Plots							14.14	
L-39:	San Dimas #212							16.54	
L-40:	Bell Watershed							18.00	
L-41:	Tanbark Climatic	1.25	3.66	3.35	11.24	1.39	0.32	21.30	2700
L-42:	Browns Flat							22.38	
L-43:	Fern #2 Gage							23.94	
L-44:	San Dimas RG #6							19.31	
L-45:	Mouth San Antonio Canyon	0.98	3.34	2.35	accum:	10.17		16.84	2250
L-46:	East Ford	1.72	5.05	3.31	accum:	15.76		25.84	5740
L-47:	Big Pines	2.05	1.58	1.66	6.58	4.81		16.68	6860
L-48:	Table Mt.	1.80	1.40	.88	4.59	1.71		10.38	7500
L-49:	Dume Canyon	0.75	2.90	4.18	6.00	2.20		16.03	1500
L-50:	Topanga R. S.	1.27	3.03	3.17	6.70	0.16		14.33	747
L-51:	Van Nuys	0.17	1.53	2.46	2.27	3.29	0.02	9.74	695
L-52:	N. Hollywood	1.40	1.30	1.83	5.32	0.28		10.13	700
L-53:	Burbank	0.07	1.26	1.92	0.70	2.85	0.21	7.01	560
L-54:	Sunset Canyon	1.29	2.01	2.44	6.78	0.73		13.25	1650
L-55:	Rossmoyne	1.15	2.18	2.10	7.10	0.80	0.06	13.39	740
L-56:	Brand Park	1.33	2.08	2.54	7.02	0.76		13.73	1250
L-57:	Glendale	0.55	2.78	2.50	3.35	4.87	0.29	14.34	526
L-58:	Devils Gate	1.31	2.38	2.38	9.55	1.08		16.70	1100
L-59:	Pasadena	1.72	2.53	2.18	7.70	0.68		14.81	800
L-60:	Cal Tech.	1.62	2.72	2.27	5.60	0.62		14.77	763
					1.94 PM				
L-61:	Alhambra		4.02	1.88	7.11	0.59		13.60	456
*L-62:	Los Angeles City	0.10	1.54	2.76	1.38	4.98	0.30	11.06	261
*L-62:	" " "	1.20	1.67	1.76	5.88	0.36		10.87	260
L-63:	Hancock Park	1.26	1.75	1.65	5.50	0.40		10.56	177
L-64:	Curson Canyon	1.48	2.05	1.94	6.25	0.45		12.17	1125
L-65:	Up. Franklin R.	1.42	2.14	2.26	4.62	0.45		10.89	867

* Official Weather Bureau

** Roof - L.A.F.C. Dist.

RAINFALL

LOS ANGELES COUNTY - (cont.)

Station	2/27	2/28	3/1	3/2	3/3	3/4	Total	Elev.
1-51: Avenue P. R.	1.37	2.80	2.60	2.17	1.61		11.55	1000
1-52: Glenahoy	2.12	3.05	2.77	1.57			13.51	800
1-53: Big Dalton Dam	1.24	3.66	3.42	0.07			14.97	1575
1-54: San Dimas							17.56	
1-55: San Dimas R. S.							18.56	
1-56: San Gabriel	0.15	2.85	2.30	1.92	0.16	0.13	18.49	1700
1-57: San Gabriel Camp	1.15	3.75	3.12	12.32	1.17		21.99	1700
1-58: San Dimas	1.14	2.32	2.90	7.18	1.24		14.68	1550
1-59: San Dimas Pecos							14.14	
1-60: San Dimas							16.54	
1-61: San Dimas							18.00	
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* Official Weather Bureau
** Recd - L.A.P.C. Dist.

RAINFALL

LOS ANGELES COUNTY - (cont.)

Station	2/27	2/28	3/1	3/2	3/3	3/4	Total	Est.
L-66: U. C. L. A.	0.27	2.19	2.66	1.60	1.51	0.03	11.56	18
L-67: Bel Air	1.58	2.02	2.00	2.83	0.21		12.64	51
L-68: Beverly Hills	1.12	2.21	1.79	6.08	0.30		11.83	28
L-69: Santa Monica	0.25	2.50	1.52	3.65	1.20	0.03	9.15	51
L-69: Santa Monica	0.80	1.90	1.56	1.11	0.85		9.22	51
L-70: Culver City	0.17	1.56	2.25	2.82	3.11	0.11	10.08	20
L-71: Huntington Park							9.18	
L-72: Montebello							9.73	20
L-73: Bell							9.68	15
L-74: Downey	1.65	0.51	1.17	2.12AM	0.17		3.05	11
L-75: Whittier	1.28	0.67	1.65	1.50	0.73		8.83	26
L-76: Baldwin Park							11.26	30
L-77: Baddingstone	1.09	1.61	1.68	5.15	1.15		11.01	103
L-78: Pomona	0.12	1.15	2.11	2.17	1.21		10.06	87
L-79: Inglewood							8.61	10
L-80: L. S. Van. Airport	0.30	1.15	1.71	2.03	1.96	0.11	7.26	15
L-81: Hawthorne							8.21	5
L-82: Hermosa Beach							6.99	1
L-83: Redondo Beach							7.65	1
L-84: Gardena							7.65	5
L-85: Compton							8.68	5
L-86: Santa Pedro	0.09	0.85	1.53	0.90	1.28	0.15	5.10	25
L-87: Long Beach	1.10	1.63	0.58	3.30	0.17		7.38	25
L-88: Artesia							8.91	150
L-89: Sierra Madre	0.56	5.51	2.69	9.18	1.03		17.00	1100

VENTURA COUNTY

Tab.:		:	:	:	:	:	:	:	:	Est.							
No. :	STATION	:	2/27	:	2/28	:	3/1	:	3/2	:	3/3	:	3/4	:	Total	:	Elev.
V-1	:Sheldon Ranch	:	0.19	:	1.18	:	2.65	:	8.27	:	0.75	:		:	13.04	:	900
V-2	:Casitas Ranch	:		:	1.10	:	2.70	:	3.00	:	3.00	:		:	9.80	:	400
V-3	:Santa Paula	:		:	0.88	:	2.10	:	3.24	:	3.25	:		:	8.47	:	210
V-4	:Ventura	:		:		:		:		:		:		:	7.25	:	43
V-5	:Oxnard	:	0.70	:	1.89	:	3.30	:	1.66	:	0.01	:		:	7.56	:	45
V-6	:Las Posas Area	:		:	2.7	:	0.4	:	4.7	:		:		:	7.8	:	1100
V-7	:Somis	:		:		:		:		:		:		:	7.98	:	120
V-8	:Moorpark	:		:		:		:		:		:		:	7.35	:	508
V-9	:Simi	:		:		:		:		:		:		:	6.56	:	480
V-10	:Fillmore	:		:		:		:		:		:		:	9.09	:	469
V-11	:Piru	:		:		:		:		:		:		:	8.97	:	740
V-12	:Ojai	:		:		:		:		:		:		:	9.25	:	480
V-13	:Hueneme	:		:		:		:		:		:		:	6.80	:	40
V-14	:Camarillo	:		:		:		:		:		:		:	7.34	:	140
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VENTURA COUNTY

RAINFALL

Tab. No.	STATION	2/27	2/28	3/1	3/2	3/3	3/4	Total	Ref.
V-1	Sheldon Ranch	0.19	1.18	2.65	0.27	0.75		13.04	9
V-2	Cassitas Ranch	0.25	1.10	2.70	3.00	3.00		9.80	14
V-3	Santa Paula	0.17	0.88	2.10	3.24	3.25		8.47	21
V-4	Ventura							7.25	1
V-5	Ormond	0.70	1.89	3.30	1.66	0.01		7.56	1
V-6	Las Posas Area	1.22	2.7	0.4	4.7			7.8	110
V-7	Somis	1.22	0.87	1.65	2.30	0.75		7.98	12
V-8	Moortpark	1.22	1.2	1.68	2.15	2.15		7.35	50
V-9	Stimi	0.72	1.12	2.12	2.17	2.17		6.56	14
V-10	Willmore	0.72	1.12	1.75	2.17	2.17		9.09	14
V-11	Piru							8.97	71
V-12	Olaf							9.25	14
V-13	Hueneme							6.80	1
V-14	Camarillo	0.72	1.12	1.65	2.30	2.30		7.34	14

RIVERSIDE COUNTY

Tab.:		:	:	:	:	:	:	:	:	Est.
No. :	STATION :	2/27 :	2/28 :	3/1 :	3/2 :	3/3 :	3/4 :	Total :	Elev.	
R-1 :	Riverside :	0.12 :	0.93 :	0.96 :	0.68 :	2.15 :	0.42 :	5.26 :	895	
R-2 :	U.C.Citrus Sta..21 :	0.52 :	1.10 :	0.71 :	2.56 :	0.18 :	5.28 :	900		
R-3 :	Corona :	0.15 :	1.35 :	1.35 :	1.05 :	4.30 :	0.60 :	8.80 :	850	
R-4 :	Cajalco :	1.13 :	0.70 :	1.58 :	1.37 :	4.78 :	1300			
R-5 :	San Corgonie:	2.50 :	3.50 :	1.50 :	12.15 :	0.75 :	0.25 :	20.65 :	3250	
R-6 :	Hurley Flats:	0.29 :	2.00 :	1.80 :	0.74 :	6.26 :	0.96 :	12.05 :	3600	
R-7 :	San Jacinto :	0.85 :	0.32 :	1.28 :	2.15 :	1.15 :	0.18 :	5.93 :	1564	
R-8 :	Hemet :	0.65 :	0.22 :	1.65 :	0.78 :	2.07 :	0.13 :	5.50 :	1700	
R-9 :	Perris :	1.00 :	0.55 :	1.15 :	1.10 :	2.63 :	0.12 :	6.55 :	1500	
R-10 :	Elsinore :	1.00 :	1.43 :	1.07 :	0.93 :	4.41 :	0.43 :	9.27 :	1230	
R-11 :	Deckers Ranch	0.50 :	1.74 :	3.00 :	3.10 :	6.73 :	0.90 :	16.39 :	5600	
R-12 :	Idlewild :	accum:	1.36 :	2.07 :	1.42 :	5.73 :	1.14 :	12.12 :	5300	
R-13 :	Dam H Hemet :	0.68 :	1.55 :	0.82 :	5.38 :	0.51 :	8.94 :	5000		
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RAINFALL

RIVERSIDE COUNTY

Tab. No.	STATION	2/27	2/28	3/1	3/2	3/3	3/4	Total	Elev.
R-1	Riverside	0.12	0.25	0.25	0.68	2.15	0.12	5.25	895
R-2	U.C. Citrus Sta.	0.21	0.52	1.10	0.71	2.56	0.18	5.28	900
R-3	Corona	0.15	1.35	1.35	1.05	1.30	0.60	6.80	850
R-4	Cajalco	1.13	0.70	1.58	1.37			14.78	1300
R-5	San Geronimo	2.50	3.50	1.50	12.15	0.75	0.25	20.65	3250
R-6	Hurley Plaza	0.29	2.00	1.80	0.74	6.26	0.26	12.05	3600
R-7	San Jacinto	0.35	0.32	1.22	2.15	1.15	0.18	5.23	1564
R-8	Hemet	0.65	0.22	1.65	0.76	2.07	0.13	5.50	1700
R-9	Perris	1.00	0.55	1.15	1.10	2.65	0.12	6.55	1500
R-10	Wainwright	1.00	1.15	1.07	0.95	1.11	0.13	9.27	1230
R-11	Decker's Ranch	0.50	1.74	3.00	3.10	6.73	0.20	16.39	5600
R-12	Idlawild	1.36	2.07	1.42	5.73	1.14	1.14	12.12	5300
R-13	San W. Hemet	0.68	1.55	0.82	5.38	0.51		8.94	5000

SAN BERNARDINO COUNTY

Tab.:	STATION	2/27	2/28	3/1	3/2	3/3	3/4	Total	Est. Elev.
S-1	Camp Baldy		3.95	4.50	12.00	2.78		23.23	4300
S-2	Lytle Creek	2/27 to 3/2	-10.00	3/2-3/4	-18.00			28.00	3250
S-3	Bennit Ranch		5.50			8.00	1.78	15.28	3800
S-4	Sawpit Canyon	2/19 to 3/1	-11.24	3/1 to 3/3	-17.34			28.58	
S-5	Devil Canyon							28.	3100
S-6	Devore	.38	3.40	3.12	1.68	7.35		15.93	2960
S-7	Devil Canyon	.19	2.13	2.40	1.91	6.73	.24		
						(3.5-	.05	13.65	2000
S-8	Newmark	.23	1.93	1.93	1.65	6.02	.75		
						(3/5-	.06	12.57	1800
S-9	Del Rosa	1.20	1.15	1.66	1.69	6.38	.12	12.20	2700
S-10	Lake Arrowhead	0.35	7.40	4.33	3.40	14.51		30.49	5000
S-11	Big Bear Dam	0.34	4.62	3.39	1.54	15.06	2.00	26.95	6800
S-12	Pine Knot							18.60	7250
S-13	Seven Oaks	1.42	0.98	2.10	8.47	4.69	0.56	18.22	5000
S-14	Santa Ana #3	1.38	0.84	1.03	2.90	3.26	0.08		
						(3/5-	.43	9.92	2500
S-15	Mill Creek #3	1.16	0.92	1.31	3.57	3.40	0.23		
						(3/5-	0.33	10.92	2250
S-16	Raywood	4.00	3.50	1.85	13.50	0.85	0.03	23.73	7200
S-17	Redlands	1.10	0.44	1.05	1.66	3.08	0.20	7.53	1360
S-18	Gage Canal Headgates	0.16	1.62	1.00	0.92	3.95	0.55		
						(3/5-	.15	8.35	
S-19	2nd & D Sta. San Berdo	0.41	1.67	1.38	1.04	4.84	0.25		
						(3/5-	.31	9.90	1200
S-20	San Bernardino	1.36	1.10	1.34	4.46	1.56		9.82	1054
S-21	Lytle Creek	0.30	1.60	1.72	1.60	5.04	.58		
						(3/5-	.68	11.52	
S-22	Uplands	0.10	1.42	3.13	2.25	5.29		12.19	1850
S-23	Ontario	0.73	0.90	1.60	3.54	2.95		9.72	991
S-24	Chino							7.00	714
S-25	Carbon Canyon	0.15	1.95	1.76	2.80	2.70	.15	9.51	1150

RAINFALL

SAN BERNARDINO COUNTY

Sta.	No.	STATION	2/27	2/28	3/1	3/2	3/3	3/4	Total	Elev.
8-1	8-1	Camp Baldy	3.95	1.50	12.00	2.78			20.23	14500
8-2	8-2	Lytle Creek	2/27 to 3/2	10.00	3/2-3/4-18.00				28.00	32500
8-3	8-3	Devil's Ranch	5.50		8.00	1.78			15.28	3800
8-4	8-4	Sanquit Canyon	2/19 to 3/1	11.24	3/1 to 3/2-17.34				28.58	3100
8-5	8-5	Devil Canyon							28.58	
8-6	8-6	Devore	3.38	3.40	3.12	1.68	7.35		15.93	2960
8-7	8-7	Devil Canyon	1.9	2.13	2.40	1.91	6.73	2.4	13.65	2000
8-8	8-8	Newmark	1.23	1.93	1.93	1.68	6.02	7.5	12.27	1600
8-9	8-9	Del Rosa	1.20	1.15	1.66	1.69	6.38	1.2	12.20	2700
8-10	8-10	Lake Arrowhead	0.35	7.40	1.33	3.40	14.21		30.49	5000
8-11	8-11	Big Bear Dam	0.34	1.62	3.39	1.54	15.06	2.00	26.95	6800
8-12	8-12	Pine Knot							18.60	7250
8-13	8-13	Seven Oaks	1.42	0.98	2.10	8.47	1.69	0.56	18.22	5000
8-14	8-14	Santa Ana #3	1.38	0.84	1.03	2.90	3.26	0.08		
8-15	8-15	Mill Creek #3	1.16	0.92	1.31	3.27	3.40	0.23	9.92	2500
8-16	8-16	Raywood	1.00	3.50	1.85	13.50	0.85	0.03	10.92	2250
8-17	8-17	Rehlands	1.10	0.44	1.05	1.66	3.08	0.20	23.73	7200
8-18	8-18	Gage Canal							7.23	1360
8-19	8-19	Headgate	0.16	1.62	1.00	0.92	3.25	0.25		
8-20	8-20	San Bernardino	0.44	1.67	1.38	1.04	1.04	0.25	8.35	1200
8-21	8-21	Lytle Creek	0.30	1.60	1.72	1.60	5.04	5.8	9.90	1024
8-22	8-22	Uplands	0.10	1.42	3.13	2.25	5.23		12.19	1850
8-23	8-23	Ontario	0.73	0.90	1.60	3.24	2.25		9.72	991
8-24	8-24	Chino							7.00	714
8-25	8-25	Carbon Canyon	0.15	1.25	1.76	2.80	2.70	1.5	9.21	1150

RAIN INTENSITIES

STATION	Date	Hour	Date	Hour	Time	Rain	Rain Per hour
L. A. City							
Weather Bu.	2/28	6:00AM	2/28	7:00AM	60	0.61	0.61
		7:00AM		8:00AM	60	0.25	0.25
		9:00PM		10:00PM	60	0.29	0.29
		10:00PM		11:00PM	60	0.20	0.20
		11:00PM		12:00PM	60	0.53	0.53
	3/2	7:37AM	3/2	8:37AM	60	0.90	0.90
	3/2	7:41AM	3/2	8:11AM	30	0.66	1.32
	3/2	6:17AM	3/2	8:17AM	120	1.44	0.72
Santa Ana							
County Annex	2/28	11:30PM	3/1	12:05AM	35	0.53	0.91
	3/1	10:30PM	(start max. intensity)				
	3/1	11:18PM	3/1	11:20PM	2 $\frac{1}{2}$	0.05	1.20
	3/2	3:30AM	3/2	4:00 AM	30	0.17	0.34
		3:32AM		3:34AM	2	0.05	1.50
		4:08AM		4:10 AM	2	0.07	2.10
		4:35AM		4:10 AM	5	0.08	0.96
		9:28AM		9:38 AM	10	0.15	0.90
		12:55PM		1:55 PM	60	0.60	0.60
		1:12PM		1:26 PM	14	0.20	0.86
		4:40PM		5:35 PM	55	0.23	0.25
Fullerton							
Airport	2/28	11:46PM	2/28	11:53 PM	7	0.25	2.14
	3/1	10:15AM	3/1	11:10 AM	55	0.18	0.20
		3:35PM		3:52 PM	17	0.30	1.06
		3:55PM		4:25 PM	30	0.23	0.46
		4:30PM		4:38PM	8	0.13	1.35
		4:45PM		4:55 PM	10	0.14	0.84
		5:45PM		6:02 PM	17	0.20	0.71
	3/2	12:32AM	3/2	2:05 AM	93	0.58	0.37
		4:33AM		4:43 AM	10	0.10	2.00
Irvine							
	2/28	11:57PM	3/1	12:03 AM	6	0.16	1.60
	3/1	10:35PM	(start)				
	3/2	3:05AM	3/2	3:38 AM	33	0.23	0.42
		4:00AM		4:05 AM	5	0.07	0.84
		9:30AM		9:41 AM	11	0.10	0.55
		1:41 PM		1:51 PM	10	0.15	0.90
		5:02PM		5:40 PM	38	0.24	0.38
		5:54PM		6:00 PM	6	0.06	0.60

RAIN INTENSITIES

STATION	Date	Hour	Time	Rain	Per hour
L. A. City Weather Bu.	2/28	6:00AM	7:00AM	60	0.61
		7:00AM	8:00AM	60	0.25
		8:00AM	9:00AM	60	0.25
		9:00AM	10:00AM	60	0.25
		10:00AM	11:00AM	60	0.25
		11:00AM	12:00PM	60	0.25
	3/2	7:30AM	8:30AM	60	0.90
	3/2	7:41AM	8:41AM	30	1.32
	3/2	8:17AM	8:17AM	120	0.72
Santa Ana County Annex	2/28	11:30PM	12:00AM	35	0.91
	3/1	10:30PM (start max. intensity)	11:30PM	25	1.20
	3/1	11:18PM	12:00 AM	30	0.24
	3/2	3:30AM	3:30AM	2	1.70
		3:32AM	3:32AM	2	2.10
		4:08AM	4:10 AM	2	0.96
		4:35AM	4:38 AM	10	0.90
		9:28AM	1:25 PM	60	0.60
		12:52PM	1:25 PM	14	0.86
		1:12PM	2:35 PM	25	0.25
		4:40PM			
Fullerton Airport	2/28	11:40PM	11:55 PM	7	2.14
	3/1	10:15AM	11:10 AM	25	0.20
		3:35PM	3:55 PM	17	1.06
		3:55PM	4:25 PM	30	0.46
		4:30PM	4:38PM	8	1.35
		4:45PM	4:55 PM	10	0.84
		5:45PM	6:05 PM	17	0.71
	3/2	12:32AM	2:05 AM	23	0.37
	3/2	1:13AM	4:13 AM	10	2.00
Irvine	2/28	11:57PM	12:05 AM	6	1.60
	3/1	10:35PM (start)	3:38 AM	33	0.42
	3/2	3:05AM	4:05 AM	2	0.84
		4:00AM	9:41 AM	11	0.25
		9:30AM	1:51 PM	10	0.90
		1:41 PM	2:40 PM	38	0.38
		5:02PM	6:00 PM	6	0.60
		5:51PM			

RAIN INTENSITIES (cont.)

STATION	From Date	Hour	To Date	Hour	Time	Rain	Rain Per hour
Del Rosa	3/1	6:50PM:	3/1	6:55PM:	5	0.18	2.16
		6:45PM:		6:55 PM:	10	0.24	1.14
	3/2	3:30PM:	3/2	4:00 PM:	30	0.48	-.96
		4:40PM:		5:10 PM:	30	0.48	0.96
		3:00PM:		4:00 PM:	60	0.90	0.96
Univ. of Cal	3/1	12:20AM:	3/1	12:25 PM:	5	0.07	0.84
Citrus Sta.		12:42 ¹ / ₂ AM:		12:45 PM:	2 ¹ / ₂	0.07	1.68
	3/2	5:45PM:	3/2	6:45 PM:	60	0.42	0.42
Opids Camp	3/2	6:00AM:	3/2	6:20 AM:	20	0.32	0.96
		6:20AM:		6:30 AM:	10	0.15	0.90
		9:15AM:		9:50 AM:	35	1.15	1.97
		9:50AM:		10:25 AM:	35	0.74	1.27
		11:22AM:		11:50 AM:	28	0.51	1.09
		11:50AM:		12:20 PM:	30	0.63	1.26
		12:20PM:		12:35 PM:	15	0.42	1.68
		12:35PM:		1:10 PM:	35	0.79	1.47
		1:10PM:		1:40 PM:	30	0.62	1.24
		1:40PM:		1:50 PM:	10	0.38	2.28
		1:50PM:		2:10 PM:	20	0.60	1.80
		2:10PM:		2:35 PM:	65	1.03	0.95
	(Note - 10.89 inches in 8 hours)						
Lake Arrow- head	3/2	8:00AM:		12:00 N	4 hrs.	2.10	0.52
		12:00 N:		4:00 PM:	4 "	3.80	0.95
		4:00PM:		6:00 PM:	2 "	3.10	1.55
		6:00PM:		9:00 PM:	2 "	0.90	0.45
		8:00PM:		10:00 PM:	2 "	0.95	0.47
		10:00PM:		12:00 PM:	2 "	0.70	0.35
	3/3	12:00 M:	3/3	2:00 AM:	2 "	0.61	0.30
		2:00AM:		4:00 AM:	2 "	0.63	0.34
		4:00AM:		6:00 AM:	2 "	1.12	0.56
		6:00AM:		8:00 AM:	2 "	0.55	0.27
Big Bear Dam	3/2	7:00AM:	3/2	12:00 N	5 "	5.30	1.06
		12:00 N:		5:00 PM:	5 "	4.75	0.95
		5:00PM:		12:00 M	7 "	3.57	0.51
		12:00 M:		7:00 AM:	7 "	1.44	0.21

RAIN INTENSITIES (cont.)

STATION	From Date	Hour	To Date	Hour	Time	Rain	Rain Per hour
Del. Ross	3/1	6:50 PM	3/1	6:55 PM	5	0.18	2.16
		6:55 PM		7:00 PM	10	0.24	1.14
	3/2	7:30 PM	3/2	7:40 PM	30	0.48	0.96
		7:40 PM		7:50 PM	30	0.48	0.96
		7:50 PM		8:00 PM	60	0.90	0.96
Univ. of Cal Citrus Sta.	3/1	12:00 AM	3/1	12:25 PM	5	0.07	0.84
		12:25 PM		12:45 PM	25	0.07	1.68
	3/2	5:15 PM	3/2	6:15 PM	60	0.42	0.42
Opida Camp	3/2	6:00 AM	3/2	6:20 AM	20	0.32	0.96
		6:20 AM		6:30 AM	10	0.12	0.90
		6:30 AM		6:50 AM	35	1.12	1.97
		6:50 AM		7:05 AM	35	0.74	1.37
		7:05 AM		7:20 AM	28	0.51	1.09
		7:20 AM		7:30 PM	30	0.62	1.26
		7:30 PM		7:45 PM	15	0.42	1.68
		7:45 PM		8:10 PM	35	0.79	1.47
		8:10 PM		8:40 PM	30	0.62	1.24
		8:40 PM		9:10 PM	10	0.58	2.28
		9:10 PM		9:40 PM	20	0.60	1.80
		9:40 PM		10:10 PM	65	1.03	0.25
(Note - 10.89 inches in 8 hours)							
John Arrow-head	3/2	8:00 AM		12:00 M	4 hrs.	2.10	0.52
		12:00 M		1:00 PM	1	3.80	0.92
		1:00 PM		6:00 PM	5	3.10	1.52
		6:00 PM		9:00 PM	3	0.90	0.42
		9:00 PM		10:00 PM	2	0.22	0.47
		10:00 PM		12:00 PM	2	0.70	0.35
	3/3	12:00 M		2:00 AM	2	0.61	0.30
		2:00 AM		4:00 AM	2	0.62	0.34
		4:00 AM		6:00 AM	2	1.12	0.56
		6:00 AM		8:00 AM	2	0.52	0.21
Big Bear Dam	3/2	7:00 AM	3/2	12:00 M	5	2.30	1.06
		12:00 M		5:00 PM	5	4.75	0.92
		5:00 PM		12:00 M	7	3.57	0.51
		12:00 M		7:00 AM	7	1.44	0.21

RAIN INTENSITIES (Cont.)

STATION	From	To	Time	Rain	Rate
	Date	Hour	Date	Hour	per hour
Bell Volfe	3/2	2:30 PM	3/2	2:45 PM	15 : 0.21 : 0.84
		2:30 PM		3:00 PM	30 : 0.40 : 0.80
		2:30 PM		3:30 PM	60 : 0.78 : 0.78
		5:00 AM		5:00 PM	12 hrs : 7.26 : 0.61
Tanbark	3/2	2:00 PM	3/2	2:15 PM	15 : 0.33 : 1.32
		2:15 PM		2:45 PM	30 : 0.64 : 1.28
		2:00 PM		3:00 PM	60 : 1.25 : 1.25
		5:00 AM		5:00 PM	12 hrs : 11.01 : 0.92
4350 W. S.	3/2	1:00 PM	3/2	1:15 PM	15 : 0.33 : 1.32
		1:00 PM		1:30 PM	30 : 0.59 : 1.18
		1:00 PM		2:00 PM	60 : 1.09 : 1.09
		5:30 AM		5:30 PM	12 hrs : 8.67 : 0.72
Fern S.R.E.	3/2	1:00 PM	3/2	1:45 PM	15 : 0.45 : 1.70
		1:00 PM		1:30 PM	30 : 0.78 : 1.56
		1:30 PM		2:30 PM	60 : 1.56 : 1.56
		5:00 AM		5:00 PM	12 hrs : 11.15 : 0.93
Big Rock Cr.	3/2				9 hrs : 9" : 1.00
Raywood Flats	3/1	1:00 AM	3/3	8:30 AM	15.35 : 1.07
Mt. Wilson	3/1	9:00 PM	3/2	9:00 PM	12 hrs : 12.81 : 1.07
Aliso Creek	3/2			20 hrs	: 4.00" : 0.20
" "				10	: .25 : 1.50
Pine Knots	3/2	7:00 AM	3/2	5:00 PM	10 hrs : 10.40 : 1.04
Upper San Cor-					
gonio Plant	3/2		3/3	24 hrs	: 12:00 : 0.50
Raywood Flat					
Intake	3/2		3/3	24 hrs	: 15.25 : 0.64
Los Pasos					
Area	3/2			20 hrs	: 4.70 : 0.23
				13 "	: 4.00 : 0.30
				1 hr	: 0.66 : 0.66
				10	: 0.20 : 1.2
				4	: 0.10 : 1.5

RAIN INTENSITIES (Cont.)

STATION	From	To	Rate	Time	Rate	Rate
	Date	Date	Hour	Hour	per hour	per hour
Bell Vofe	3/2	3/2	2:30 PM	2:45 PM	0.81	0.81
			2:30 PM	3:00 PM	0.40	0.80
			2:30 PM	3:30 PM	0.78	0.78
			2:00 AM	2:00 PM	7.25	0.61
Tamark	3/2	3/2	2:00 PM	2:15 PM	0.33	1.32
			2:15 PM	2:45 PM	0.61	1.28
			2:00 PM	3:00 PM	1.25	1.25
			2:00 AM	2:00 PM	11.01	0.22
1550 W. S.	3/2	3/2	1:00 PM	1:15 PM	0.33	1.32
			1:00 PM	1:30 PM	0.59	1.18
			1:00 PM	2:00 PM	1.09	1.09
			2:30 AM	2:30 PM	6.67	0.72
Term S.R.E.	3/2	3/2	1:00 PM	1:15 PM	0.45	1.70
			1:00 PM	1:30 PM	0.78	1.56
			1:30 PM	2:30 PM	1.56	1.56
			2:00 AM	2:00 PM	11.15	0.93
Big Rock Cr.	3/2	3/2			9 hrs	1.00
Raywood Plaza	3/1	3/2	1:00 AM	2:30 AM	12.35	
Mt. Wilson	3/1	3/2	2:00 PM	2:00 PM	12.81	1.07
Aliso Creek	3/2	3/2			20 hrs	0.20
"					10	1.50
Pine Knots	3/2	3/2	7:00 AM	2:00 PM	10.40	1.04
Upper San Cor-						
Gonio Plant	3/2	3/2			24 hrs	0.50
Raywood Flat	3/2	3/2			24 hrs	0.64
Intake	3/2	3/2			24 hrs	0.64
Los Pasos	3/2	3/2			20 hrs	0.23
Area					15	0.30
					1 hr	0.66
					10	1.2
					4	1.5

SNOW RECORDS ESTIMATES

	: 2/27	: 2/28	: 3/1	: 3/2	: 3/3	: Elev.
Big Bear	: 8"	:	:	:	:	:
Big Pines	: 18"	: 18"	: 18"	: 16"	: 20"	: 6860
Table Mt.	: 24"	: 24"	: 24"	: 24"	: 24"	: 7500
Blue Ridge	: 38"	: 36"	: 36"	: 36"	: 36"	: 8300
Jackson Lake	: 10"	: 8"	: 8"	: 6 "	: 8"	: 6200
Mt. Wilson	: none	: 1 1/2"	:	:	:	: 5850
Lake Arrowhead	: Patches:	:	:	:	:	: 5000
Idlewild	: patches:	:	:	:	:	: 5300
Crystal Lake	:	:	:	:	:	: 5740
East Pine	: 10"	: 5"	:	: Patches	: Patches	:
West Pine	: Patches:	: Patches	:	: Patches	:	:
Ski Jump Baldy	: 4'-5'	:	:	:	:	: 7800
Raywood Flats	:	:	:	: 2 1/4"	:	: 7200
Santa Ana and Elsinore Mts.	:	: None	:	:	:	: 5000
	:	:	:	:	:	: :
	:	:	:	:	:	: :

Locality	2/27	2/28	3/1	3/2	3/3	Elev.
Big Bear	8"					
Big Pines	18"	18"	18"	18"	18"	6660
Table Mt.	24"	24"	24"	24"	24"	7500
Blue Ridge	38"	36"	36"	36"	36"	6300
Jackson Lake	10"	8"	8"	6"	8"	6200
Mt. Wilson	none	2"				5850
Lake Arrowhead	patches					5000
Idaho	patches					5300
Crystal Lake						
East Pine	10"	5"				5740
West Pine	patches					
Elk Jump Baldy	4'-5"					7600
Raywood Flats				24"		7200
Santa Ana and Palmare Mts.	none					5000

1.00
 0.50
 0.25
 0.10
 0.05

FLOOD PHOTOGRAPHS



CAL-4251

CAL-4251 - John Arneill property located in the Camarillo District. This property was planted to flax previous to the storm of March 2. Soil is a sandy loam lying on approximately a 1% slope. No erosion control measures on this farm. Washes and gullies created by March 2 storm on approximately 1/2 of 65-acre field. Estimated loss to growing crop, 65%. Thousands of tons of deposition were washed across the State Highway and deposited in valuable orange groves below which were controlled completely with a fine winter growing cover crop.



CAL-4254

CAL-4254 - Barbara Hughes' property. This property is adjacent to the Arneill property on the west. Identical as to size, slope, and soils. Planted to winter flax the same week as the Arneill property. This property controlled by broad-base terraces. Very little damage to terraces. Minor soil losses.

041-1257 - John Amrell property located in the Camille District.
This property was planted to rice previous to the year of 1912.
It is a sandy loam lying on approximately a 1% slope. No erosion
control measures on this farm. Trees and bushes located by house
about an approximately 1/2 of 50-acre field. Estimated loss to
growing crop, 50%. Thousands of tons of vegetation were washed
over the State Highway and deposited in various areas. Growers
for which were controlled completely with a fire winter growing
cover crop.

041-1258 - Barbara Hughes' property. This property is adjacent to
the Amrell property on the west. Identical as to size, slope, and
soils. Planted to winter wheat the same week as the Amrell property.
This property controlled by brush-free burnings. Very little damage

to property. Minor soil losses.



CAL-4257 - Glenn Property. Striking example of clean-cultivated land continuously farmed to beans year after year. Shows comparison between the hill in the foreground which was clean-cultivated and the hill in the background which had been retired two years, 1935 and 1936.

GALE-1957 - Steam Property. Starting example of steam-
activated land continuously turned to beans year after
year. Shows comparison between the hill in the foreground
which was steam-activated and the hill in the background
which had been retired two years, 1955 and 1956.



CAL-4253 - Mose Waters' Ranch. This 100-acre apricot grove is dry-farmed and prior to this year has been clean-cultivated during the winter months. Property under cooperative agreement at present and erosion being controlled with basin-listing and cover cropping. To date, 17 and 1/2 inches of rain have fallen on this orchard, including the rain of March 2.



CAL-4252 - Harris Hitch Ranch. This orchard lies immediately adjacent to the Waters' property. Shows soil washes and losses where no erosion control methods have been taken. Formerly, all apricot groves in this district were farmed in this manner.

DAI-422 - Moss Waters' Ranch. This 100-acre apricot grove is dry-
farmed and prior to this year has been clean-cultivated during the
winter months. Property under cooperative agreement at present and
erosion being controlled with beetle-lining and cover cropping. To
date, 17 and 1/2 inches of rain have fallen on this orchard, in-
cluding the rain of March 2.

DAI-423 - Martin's Ranch. This orchard lies immediately ad-
jacent to the Waters' property. Shows soil washes and losses where
no erosion control methods have been taken. Formerly, all apricot
groves in this district were farmed in this manner.



CAL-4259

CAL-4259 - James Hitch property. View of water and sand flowing across a ranch, off the Las Posas Area, during the storm of March 2. This picture was taken from a wagon standing in the field. Later, the wagon was nearly covered with silt and debris from the water flowing in the foreground.



CAL-4260

CAL-4260 - James Hitch property. Same view as adjoining picture but photographed on March 10. Shows condition of field after flood waters had subsided. Beginning April 1, this field is to be planted to Valencia oranges. Owner estimates cost of removing sand from field at \$250 an acre. Stock and equipment shown in picture are being used to clear the field and prepare it for the planting of oranges.

GA-1257 - Jones Hitch property. View of water and sand flowing across a ranch. Off the Lee House river, during the storm of March 2. This picture was taken from a wagon standing in the field. Later, the wagon was nearly covered with silt and debris from the water flowing in the foreground.

GA-1258 - Jones Hitch property. Same view as adjacent picture but photographed on March 19. Shows condition of field after flood waters had subsided. Beginning April 1, this field is to be planted to Valeriana oranges. Owner estimated cost of removing sand from field at \$250 an acre. Stocking equipment shown in picture are being used to clear the field and prepare it for the planting of oranges.



CAL-4256 - Hoffelt Property. Showing 33 year old English walnut grove, 9 acres in area, being covered by deposition from clean-cultivated bean land two miles distant. Measurements were taken of the deposition and the average depth was estimated as 3 feet. This deposition varies from a few inches on one part of the orchard to as much as six feet in the deepest parts. Owner considers both orchard and land a total loss.



CAL-4255 - Hoffelt property. Showing depth of deposition around 33 year old English walnut tree. Banks of excavation are of pure sand with no agricultural qualities whatever.

CAL-125 - Bell's Property. Showing 25 year old English walnut grove. 2 acres in area, being covered by deposition from clean-cutting down land two miles distant. Measurements were taken of the deposition and the average depth was estimated as 3 feet. This deposition varies from a few inches on one part of the orchard to as much as six feet in the deepest parts. Owner considers both orchard and land a total loss.

CAL-126 - Bell's Property. Showing depth of deposition around 25 year old English walnut grove. Banks of excavation are of pure sand with no agricultural particles whatever.



CAL-4511 - Citrus orchard damaged by deposition of silt and rocks on delta cone of mountain canyon. Note size of boulders transported by the flood.



CAL-4463 - Santa Clara River at Santa Paula, California, at flood stage showing typical bank erosion. Walnut trees being undermined and falling into the stream.

CAI-1512 - River channel damaged by deposition of silt and
trees on both sides of mountain range. Note state of banks
transported by the flood.

CAI-1513 - Santa Clara River at Santa Paula, California, at
flood stage showing typical bank erosion. Walnut trees being
undermined and falling into the stream.



CAL-4475 - Destruction of homes by flood water from Santa Clara River.



CAL-4510 - Citrus orchard near Ontario, California, showing deposition of drift at the mouth of a canyon.



CAL-1415 - Restoration of houses by flood water from Santa Clara River.



CAL-1410 - Caves opened near Ontario, California, showing position of ship at the mouth of a canyon.



CAL-4293 - Flood waters of the Santa Ana River breaking out from the improved channel of inadequate size.



CAL-4295 - After the flood has passed. Agricultural land covered by sand and silt.



Cal-1235 - Flood waters of the Santa Ana River breaking out from the improved channel of inadequate size.



Cal-1236 - After the flood has passed. Agricultural land covered by sand and silt.



CAL-1291 - Santa Ana River showing improved channel and adjacent area covered by flood water because of inadequate size of channel. Mouth of channel in foreground.



CAL-1299 - Santa Ana River, east of Anaheim, showing character of agricultural development that was damaged by flood waters. Damaged railroad bridge in foreground.



191-1237 - Santa Ana River showing improved channel and
adjacent area covered by flood water because of inadequate
width of channel. Photo at station in foreground.



191-1237 - Santa Ana River, canal at station, showing channel
covered by flood water because of inadequate width of channel.
Photo at station in foreground.



CAL-4281 - Flood channels from steep mountain canyons spreading over highly improved agricultural land in San Bernardino County.



CAL-4299 - Los Angeles River at Griffith Park showing rock-revetted embankments destroyed by the flood.

001-1201 - Flood channels from steep mountain canyons
spreading over highly improved agricultural land in San
Bernardino County.

001-1202 - Los Angeles River at Griffith Park showing most
reverted expenditures destroyed by the flood.



CAL-4505 - Cucamonga CCC Camp, Cal-10, damaged by overflow from Cucamonga Creek.



CAL-4503 - Cucamonga CCC Camp damaged barrack.

Cal-1507 - Occasionaly 300 Camp, damaged by overflow
from Occasionaly Creek.

Cal-1507 - Occasionaly 300 Camp damaged by overflow.



San Antonio Creek

CAL-4275 - Typical mountain terrain in southern California showing flood from canyon and highly developed agriculture on delta cone.

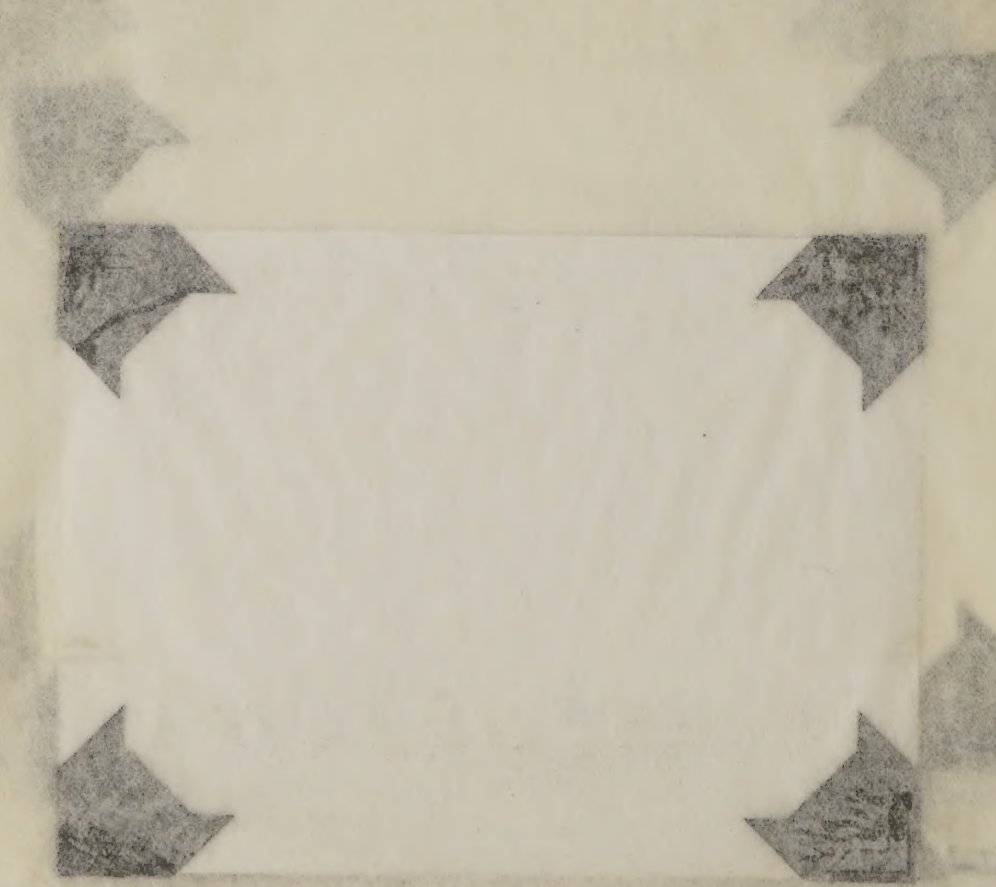


CAL-4279 - Flood waters from steep canyons spreading over delta cones.



San Antonio River

CAL-127 - Typical mountain terrain in southern California showing flood from canyon and highly developed agriculture on delta
corner.



CAL-127 - Flood waters from steep canyons spreading over delta
corner.



CAL-4512 - Flood waters of San Antonio Creek going through an orange orchard at Pomona, California.



CAL-4493 - Flood flow in the Santa Clara River at Santa Paula, California showing residences being flooded. The Soil Conservation Service Nursery lath house in middle foreground being destroyed by bank erosion. The river at this point widened its channel about one-quarter of a mile by bank erosion.

001-1512 - Flood waters of San Antonio Creek going through an orange orchard at Corona, California.

001-1513 - Flood waters of San Antonio Creek going through an orange orchard at Corona, California.

001-1514 - Flood flow in the Santa Clara River at Santa Paula, California showing residences being flooded. The Bell Company water service nursery farm house in middle foreground being destroyed by bank erosion. The river at this point widened its channel about one-quarter of a mile by bank erosion.

001-1515 - Flood flow in the Santa Clara River at Santa Paula, California showing residences being flooded. The Bell Company water service nursery farm house in middle foreground being destroyed by bank erosion. The river at this point widened its channel about one-quarter of a mile by bank erosion.



CAL-448 - Citrus orchard damaged by deposition of two feet of sand and silt.



CAL-447 - Destruction of homes by flood water from Santa Clara River.



000-1118 - Deposition of houses by flood water from Santa Clara River. The river at this point is about 100 feet wide and 10 feet deep. The houses are situated on a slight rise of the river bank.



000-1118 - Deposition of houses by flood water from Santa Clara River. The river at this point is about 100 feet wide and 10 feet deep. The houses are situated on a slight rise of the river bank.



NEV-184 - Flood waters of Meadow Valley Wash going over a 16 foot drop installed by the Soil Conservation Service to control head cutting.



NEV-185 - Meadow Valley Wash showing normal condition above the 16 foot head control drop installed by the Soil Conservation Service.

100-100 - Flood waters of Indian Valley Wash going over a 10 foot
drop installed by the Soil Conservation Service to control head
cutting.

100-100 - Indian Valley Wash showing normal condition above the 10
foot head control drop installed by the Soil Conservation Service.



NEV-277 - Meadow Valley Wash entrenching its channel in a narrow valley.



NEV-168 - Meadow Valley Wash an unprotected head cutting in a meadow valley.

1944-1945 - Meadow Valley Wash and surrounding its channel in a narrow valley.

1944-1945 - Meadow Valley Wash an unprotected head cutting in a narrow valley.

APPENDIX II

Section 2.

HYDRAULIC DATA

Runoff Comparisons, Watersheds with and without Controls, etc.

By

R. S. Goodridge
Hydraulic Engineer
Soil Conservation Service



APPENDIX - II

Section 2

Storm of February 26 - March 3, 1938

REPORT ON MAXIMUM FLOOD FLOWS WITH NOTES AND OBSERVATIONS
LOOKING TO THE STRENGTHENING OF THE DESIGN OF CONTROLS

BY

R. S. Goodridge
Hydraulic Engineer
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In March 1938 southern California, encompassed in the three major drainage systems of the Los Angeles, San Gabriel and Santa Ana Rivers, suffered the most spectacular damages from flood flows in its history. The total loss is estimated at \$83,000,000 and 74 lives. The historical record began with the founding of the San Gabriel Mission in 1771.

Greater floods are generally conceded to have occurred during the winter of 1861-2. Old residents and flood historians state that this flood was definitely greater than those of 1914 and 1916 and compares in peak flows with those of 1884 and 1889 although the floods of 1884 and 1889 were of greater volume because of the longer duration of the rains.

Location and Extent of the Los Angeles, San Gabriel and Santa Ana Basins.

The drainage systems of the Los Angeles, San Gabriel and Santa Ana Rivers emerge from the steep mountain escarpments at 30, 30, and 54 miles respectively from the Pacific Ocean and flow over the detrital cones a distance of 18 miles through the alluvial coastal plains to the sea. The areas may be circumscribed by arcs of 44, 50, and 82 miles respectively swung from the outlets. These catchments, lie in the center of the lower third of the state within latitudes $33^{\circ} - 37'$ and $34^{\circ} - 24'$ and longitudes $116^{\circ} - 34'$ and $118^{\circ} - 43'$. The overall distance east and west is 125 miles and north and south 54 miles. The total area is somewhat in excess of 4,000 square miles.

Physiography and Geology - The mountain ranges may be classed as follows:

In March 1938 southern California, encompassed in the three major drainage systems of the Los Angeles, San Gabriel and Santa Ana Rivers, suffered the most spectacular damages from flood flows in its history. The total loss is estimated at \$65,000,000 and lives. The historical record began with the founding of the San Gabriel Mission in 1771.

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Location and Extent of the Los Angeles, San Gabriel and Santa Ana Basins.

The drainage systems of the Los Angeles, San Gabriel and Santa Ana Rivers empty from the steep mountain escarpments at 30, 50, and 54 miles respectively from the Pacific Ocean and flow over the general area a distance of 10 miles through the alluvial coastal plains to the sea. The area may be circumscribed by arcs of 14, 20, and 32 miles respectively away from the outlet. These catchments lie in the center of the lower third of the state within latitudes 33° - 37° and 34° - 34° and longitudes 116° - 117° and 118° - 119°. The overall distance east and west is 125 miles and north and south 50 miles. The total area is somewhat in excess of 14,000 square miles.

Physiography and Geology - The mountain ranges may be classed as follows:

	<u>Range</u>	<u>Elevation</u>
Coastal Range	Santa Monica Mts.	1500 - 2500
	Verdugo Mts.	1500 - 3000
	Santa Ana Mts.	1500 - 5500
Front Range	Santa Susana Mts.	2000 - 3766
	Sierra Madre Mts.	5000 - 6152
Back Range	San Gabriel Mts.	4000 - 10,080
	San Bernardino Mts.	4000 - 11,485
	San Jacinto Mts.	4000 - 10,805

These systems were formed by block-faulting of large masses of metamorphosed sediments, schists and gneisses, with intrusion of granite. The front and back ranges consist mainly of granites, diorites, schists and gneisses which have been uplifted and present the characteristics of young topography with steep slopes which become unstable to a marked degree when subjected to continued rains. As a result, extensive cones of detrital material have been built up by the interlacing flows of heavily charged surface run-offs. In general, these cones are built out from the escarpments at the 1000 foot elevation in the Los Angeles and San Gabriel basins and at 2000 feet in the Santa Ana Basins. The Gradients of the cones range from 15 to 1 per cent. The cones extend to the front range mountains and hill "narrows" and emerge at about an elevation 250 feet to the coastal plains which extend a distance of about 18 miles to the ocean on gradients which average 0.26 per cent or about $1\frac{1}{4}$ feet to the mile. The relative profiles of the three systems are shown on Figure 1. The profile distance is the approximate thalweg length as obtained from the 1:250,000 U. S. G. S. map. The cones have a large capacity for seepage and in-

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	San Jacinto Mts.	1000 - 10,805

infiltration from surface flows and valley rainfall. Rising waters occur at the "narrows" and may flow out to the ocean as the alluvial deposits stratified with clay lenses support many perched water tables to the extent that there is limited benefit from valley rainfall to counter-balance the effects of irrigation and water supply pumping. The reaction in water tables is so great in dry periods that salt water intrusion has been noted.

Soils

Soils are widely ranged in texture and in their associated infiltration capacities both with respect to rate and amount. They vary from gravelly sands to silt loams, clays and adobes. The infiltration capacities with respect to rates vary from extremes of about 12 inches per hour on upper cones to 4.5" and 1.0" per hour on soils below field capacity. The clays and adobes are not extensive and have limited infiltration capacities of about 0.25 inches or less per hour.

Vegetal Cover

The mountains and rough hill lands are generally covered by the natural climax vegetation except on those areas which have been burned and are in the recovery succession stage. There is limited grazing. Agricultural lands are intensively developed and are among the richest in the United States. There are extensive citrus and vineyard developments with orchards of walnuts, olives, and avacados. The latter have crept up on the hill lands and present areas specially in need of soil conservation methods. The region is developing cover crops to minimize surface erosion.

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Industrial and Urban Development

The area is rapidly attracting new capital and enjoys an accelerating population increase. In 1875 Los Angeles County had a population of 10,000. Today the population is well over 2,500,000. In 63 years the population has increased 250 times.

Rainstorms

There are two distinct types of rainstorms in this region. The more common is that which comes in on westerly winds off the ocean when the areas of high barometric pressure is moved out of its normal position off the coast. On these occasions, as in 1934, the moisture laden air is forced to rise orographically in passing over the east-west and southeasterly mountain ranges. This type apparently does not develop torrentially high intensities. In 1934 and 1938 about an inch an hour fell for 12 to 18 hours with short intensities rarely exceeding two inches an hour for 5 or 10 minute intervals.

Type two is called the "Sonora" type and is associated with southwesterly and southeasterly cyclones. Torrential intensities result. An example is the storm of August 12, 1891 at Camp California, during which 16.10 inches fell in 24 hours and 11.50 inches in 80 minutes. The damaging Techachapi storm of September 1933 was of this type. Such storms cover much more limited areas than that of the past storm, but are nevertheless threats to the smaller catchments.

The season of rainfall is crowded into the winter period from December to April when 75 per cent of the total is received with most of that amount distributed between one or two storms. Following are historical notes on past persistencies of rain:

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Duration of Rains

1825 -

1839 - 40 40 days and nights with little cessation.

1861 - 2 30 days beginning December 24. For ~~amon~~.it
rained steadily - sun scarcely shone 40 days
6 weeks at end rain set in more heavily causing
big flood.

1884 18 days February 1 to 18.

29 days March 3 to 31.

1889 26 days December 1 to 26.

1914 4 days February 18 to 21.

1916 29 days January 1 to 29.

1938 6 days February 27 to March 4.

It is appropriate to comment on the unenviable fact that southern California is in possession of the world's record for rainfall in one minute. 0.92 inches and 1.03 inches at Opid's Camp near Mount Wilson in the West Fork of the San Gabriel Canyon on April 5, 1926. The rates for the minute are 55 and 62 inches per hour. When it is considered that the two gages were removed from the area of greatest physical damage it is not surprising that the intensities correlate with the "Sonora" rain at Camp of 11.50 inches in 80 minutes or 8.62 inches per hour as the average intensity for the period. The above rates were examined in accordance with the Grunsky law for an index of the limiting intensities to be anticipated when given a cumulated record for a period of hours. These intensities equal the greatest observed for any region in the United States including Texas and are about 70 per cent of the maximum rates reported for the world.

1885 -	10 days and nights with little cessation.
1889 - 10	30 days beginning December 24. For amount.
1891 - 2	rained steadily - sun scarcely above 10 days
	6 weeks at end rain set in more heavily causing
	big flood.
1894 -	18 days February 1 to 18.
	29 days March 5 to 31.
1899	26 days December 1 to 26.
1911	14 days February 18 to 31.
1916	29 days January 1 to 29.
1938	6 days February 27 to March 1.

It is appropriate to comment on the remarkable fact that southern California is in possession of the world's record for rainfall in one minute. 0.92 inches and 1.07 inches at Opid's Camp near Mount Wilson in the West Park of the San Gabriel Canyon on April 2, 1926. The rates for the minute are 55 and 62 inches per hour. When it is considered that the two eyes were removed from the area of greatest physical damage it is not surprising that the intensities correlated with the "Sonora" rain at Camp of 11.50 inches in 60 minutes or 8.62 inches per hour as the average intensity for the period. The above rates were examined in accordance with the Grunsky law for an index of the limiting intensities to be anticipated when given a cumulated record for a period of hours. These intensities equal the greatest observed for any region in the United States including Texas and are about 70 per cent of the maximum rates reported for the world.

Critical Period of the Storm

Important in the design of flow control structures is the position which the critical period of the storm takes in the capital flood sequence of intensities. This is generally conceded to be during the later half of the storm and appears to occur after approximately three-fourths of the storm period has passed and after a similar ratio of the storm total has been cumulated. Opid's Camp record is shown for an example:

<u>Approximate</u>		<u>Storm period</u>		<u>Critical period</u>		
Date	<u>Amount</u>	<u>Time</u>	<u>Amount</u>	<u>Time</u>	<u>Amount</u>	<u>Time</u>
	<u>Total</u>	<u>Total</u>	<u>Cumulated</u>		<u>Storm total</u>	
	<u>Inches</u>	<u>Hours</u>	<u>Inches</u>	<u>Hours</u>	<u>Percent</u>	
April 4-5, 1926	10.5	16	7.5	12	71	75
Feb. 27 - Mar. 3, -1938	18.5	60	14.75	18	80	70

This phenomenon is significant because the available storage in the more shallow soil mantle, and also that provided by impounding and detention dams is to degree occupied before the critical flood-producing intensities occur, consequently the dams are forced into action with decreased flood regulation efficiency. Similarly the soil, acting as a detention reservoir if above freezing temperatures, may be completely saturated if the depth of the cover has a water-holding capacity which is less than the amount of water infiltrated from rainfall cumulated before the critical period. Assuming the Opid rainfall as given above and that a third of the soil depth was available for water storage a runoff of 100 per cent would occur from the soils with less than 22 inches and 44 inches depth respectively in 1926 and 1938. This feature largely accounts for the high volume coefficients of runoff obtained during prolonged storms. Values from the 1916 storm south of this area above San Diego ranged from 39 to 77 per cent on basins, as the San Luis Rey which is admittedly more absorbent than the

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<u>Approximate</u>		<u>Storm period</u>		<u>Critical period</u>	
Date	Amount	Time	Amount	Time	Amount
	Total	Total	Cumulative	Storm total	Percent
Inches	Inches	Hours	Inches	Hours	
April 1-5, 1926	10.5	16	7.5	12	71
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This phenomenon is significant because the available storage in the more shallow soil mantle, and also that provided by impounding and detention basins to degree occupied before the critical flood-producing intensities occur, consequently the dams are forced into action with decreased flood regulation efficiency. Similarly the soil, acting as a detention reservoir if above freezing temperatures, may be completely saturated at the depth of the cover has a water-holding capacity which is less than the amount of water infiltrated from rainfall accumulated before the critical period. Assuming the Opid rainfall as given above and that a third of the soil depth was available for water storage a runoff of 100 per cent would occur from the soils with less than 22 inches and 14 inches depth respectively in 1926 and 1938. This feature largely accounts for the high volume coefficients of runoff obtained during prolonged storms. Values from the 1916 storm south of this area above San Diego ranged from 59 to 77 per cent on basins, as the San Luis Rey which is admittedly more absorbent than the

steep slopes of this region. Preliminary data indicate that high volume coefficients were obtained during this storm from catchments above dams which furnished reliable basis for estimates of inflow.

Instability of Soil on Slopes

Infiltrated rainwaters saturated the soil mantle on slopes to depths below the root systems and weakened the resistance to sliding by both added weight and reduced friction. Many extensive slips occurred. These slips made soil and detritus available for transport by the unprecedented flood heights which were higher generally than at any time during the past fifty years. The problem of assisting nature in stabilizing these slopes is one of the major operations to be accomplished in the interest of flood control. Without it, the life and benefits of dams and stream channels are jeopardized if not doomed or local agencies will be committed to heavy maintenance and operation costs. The economy of efforts to bring about stabilization must be correlated with the economy of the upper cone debris basis which under the present practices, offers the most positive assurance of protection against the debris menace.

Run-off Rates

The available run-off data for the Los Angeles, San Gabriel and Santa Ana River and contiguous areas are shown on Tables 1 to 11. The location number identifies the position of the gaging station or estimate on the Hydrologic Map.

A study for the rainfall and characteristics throughout the world present a background for an examination of the two quantitative significance of storm types previously referred to. Fig. 3 has been prepared to show:

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Run-off Rates

The available run-off data for the Los Angeles, San Gabriel and
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of storm types previously referred to. Fig. 3 has been prepared to show:

1. Results of the March 1938 storm run-offs in the equivalent inches depth per hour run-off during the maximum rate of runoff. The rate of an inch per is equal to one cubic foot per second per acre. The striking feature of this diagram is consistency with which the preliminary and tentative estimates reflect a reasonable relation with the observed rainfall intensities which approximated an inch an hour. Most runoffs ranged from 0.4 to nearly 0.9 of an inch. The maxima are 1.11 inches for San Antonio Canyon, and 2.01 inches per hour for Banning Canyon (San Geronimo River on U.S.G.S Map, So. Calif. Hol). On closer examination it is noted that the volume measurements arrange themselves faithfully in conformity with basin characteristics.

San Gabriel Dam No. 2 area received more rain and at higher rates. See Figure 2 showing the record of intensities observed at Opid's Camp- 6.10 inches in 4.8 hours or an average intensity of 1.27 inches per hour. At Dam No. 2 the inflow crest was estimated to be 0.89 inches per hour or $.89/1.27$ or 70 percent. Also $1.27 - 0.89$ or $0.38^{\circ}/hr.$ is the total loss accountable for by a reduction in rate of the average intensity for the basin as a whole together with some infiltration in the deep sedimentary formations and the portion chargeable to the temporary channel storage.

Similarly, San Gabriel Dam No. 1 showed an inflow rate equal to 0.74 inches per hour or a loss of $1.27 - 0.74$ or 0.53 inches with undoubtedly a greater departure from the average intensity recorded at Opid's Camp for the catchment average and with increased channel storage.

Data were not available to show the ratio to the crest flow to the mean daily.

Results of the March 1938 storm run-offs in the equivalent inches depth per hour run-off during the maximum rate of runoff. The rate of an inch per is equal to one cubic foot per second per acre. The strip- ing feature of this diagram is consistency with which the preliminary and tentative estimates reflect a reasonable relation with the observed rain- fall intensities which approximated an inch an hour. Most results ranged from 0.4 to nearly 0.9 of an inch. The maxima are 1.11 inches for San Antonio Canyon, and 2.01 inches per hour for Banning Canyon (San Geronimo River on U.S.G.S Map, So. Calif., No. 1). On closer examination it is noted that the volume measurements average themselves faithfully in con- formity with basin characteristics.

San Gabriel Dam No. 2 area received more rain and at higher rates. See Figure 2 showing the record of intensities observed at Gold's Camp- 6.10 inches in 1.8 hours or an average intensity of 1.27 inches per hour. At Dam No. 2 the inflow crest was estimated to be 0.89 inches per hour or $.89 \div 1.27$ or 70 percent. Also $1.27 - 0.89 = 0.38$ or $0.38 \div 1.27$ is the total loss accountable for by a reduction in rate of the average intensity for the basin as a whole together with some infiltration in the deep sedimentary formations and the portion chargeable to the temporary channel storage.

Similarly, San Gabriel Dam No. 1 showed an inflow rate equal to 0.74 inches per hour or a loss of $1.27 - 0.74 = 0.53$ or $0.53 \div 1.27$ inches with undoubt- edly a greater departure from the average intensity recorded at Gold's Camp for the catchment average and with increased channel storage.

Data were not available to show the ratio to the crest flow to the mean daily.

Mud-Rock Flow

Notable is the estimate of the runoff made for the inflow to the Pickens Canyon debris basin of 3.06 inches per hour and the 1.08 inches per hour discharged through the spillway. Data on the intensity of the rainstorm at Briggs Terrace were not available; however, the following is observed:

The ratio of the water released to the estimated inflow is as 1 is to 2.83. On October 18, 1936 an inflow from an intensity of rainfall of 2.67" per hour produced a volumetric inflow to the basin which was measured to be 2949 cu. yds. of free water in a total of 25,011 cu. yds. equivalent to about 12 percent of free water. Assuming that one-third of the total volume of the debris was contained water, $88/3$ or 29 percent of the debris volume represents water which may be added to the 12 percent making 41 percent of interstitial water resulting in a ratio of 1 to 2.44. This estimate of bulking is in close coincidental or, likely agreement with the ratio of 1 to 2.83 estimated for the 1938 storm. These occurrences, together with other data, support the Los Angeles County Flood Control District's previous estimates which bulked the rainfall-runoff hydrograph on the order of 250 percent to approximate the mud-rock flows.

Tables showing the estimates of debris deposited in the debris basins of other areas are included in this report.

Referring back to Figure 3. Curve II shows the maximum runoff intensities as indicated from Ohio and Texas. It is thought that the southern California area can develop short-duration torrential intensities equal to any area in the United States. However, such intensities meteorologists believe could only affect relatively small areas here. This

Mud-Rock Flow

Notable is the estimate of the runoff made for the inflow to the
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rainstorm at Bridge Terrace were not available; however, the following is
observed:
The ratio of the water released to the estimated inflow is as 1 is
to 2.85. On October 18, 1936 an inflow from an intensity of rainfall of
2.67" per hour produced a volumetric inflow to the basin which was measured
to be 2049 cu. yds. of free water in a total of 25,011 cu. yds. equivalent
to about 12 percent of free water. Assuming that one-third of the total
volume of the debris was contained water, 8333 or 29 percent of the debris
volume represents water which may be added to the 12 percent making 41
percent of interstitial water resulting in a ratio of 1 to 2.44. This
estimate of bulking is in close coincidence or, likely agreement with the
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together with other data, support the Los Angeles County Flood Control
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Referring back to Figure 3, Curve II shows the maximum runoff
intensities as indicated from Ohio and Texas. It is thought that the
southern California area can develop short-duration torrential intensities
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ologists believe could only affect relatively small areas here. This

region is fortunately protected by a normal blocking "high" which wards off storms which might otherwise approach the coast. It is further protected by a relatively cold mass of water in the Pacific Ocean which serves to modify the tropical air masses sufficiently to make them more stable at the time they reach the coast. Likewise Mexican Gulf airs and the Sonoras are similarly modified and lifted orographically before reaching the region. Consequently it is claimed that the persistency and duration of the Texas storms could not form here to affect other than local limited areas.

Note the supporting volumetric measurement from Hawaii.

Curve III shows a composite of the intensities of the critical regions of the United States. Use is made of California, Texas, Pennsylvania, Colorado, Kansas and Georgia observations with the three-minute record from Porto Bello, Panama, shown to bridge the California 10-minute record and the Texas 10-minute occurrence.

Curve IV was constructed to relate the duration of these notable rains to the concentration times as observed during the 1938 storm on the San Gabriel and Santa Ana Rivers. In that manner the rainfall and runoff rates for the United States may be correlated on the collection time basis of this region which was noted during this storm.

Purpose of Figure 3. Curve II

The object in showing this curve with the local runoff data obtained in this storm is to call attention to the fact that greater storms are possible and to support the need of intensive examination of all rainstorm data available by skilled meteorologists in order that the physical conditions associated with rainstorms as individual entities may be developed

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rates for the United States may be correlated on the collection timetables

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Purpose of Figure 5. Curve II

The object in showing this curve with the local runoff data obtained

in this storm is to call attention to the fact that greater storms are

possible and to support the need of intensive examination of all rainstorms

data available by skilled meteorologists in order that the physical con-

ditions associated with rainstorms as individual entities may be developed

elaborate details could only afford a more complete view.

for a more complete interpretation of our empirically founded statistical approaches. It is possible that the 1938 storm of this region approaches the maximum possible conditions. One meteorologist commented with an evaluation of a possible 80 percent of maximum for the widespread type. He added, however, that the March 1938 storm could have been of much longer duration.

Types of Flood Waves

In the southern California coastal area some attention has been brought to frontier hydraulic phenomena which are vaguely understood, if at all. In any event, they are unpredictable to an unsatisfactory degree. The torrential character of the flow from the mountains has exhibited travel or roll waves in both natural and improved channels. The answer to the question of the economic freeboard to be used in channel design for such flow is one that engineers now need in order that flows from debris basins may be provided for without waste of public funds or inadvertently presenting a hazard. The travel waves of 1934 observed in the Verdugo channel by an engineer for the State of California have not been observed since at stages as high as they were at that time. When existing construction work is completed and a range of flows are observed, more will be known of their relative importance. It is known that the crest of the roll-waves tend to be dampened in amplitude as the stage of flow is increased in a specific reach of channel and it is hoped that the present design-allowances for their development is sufficient.

In natural channels the propagation of the flood wave and the attending configuration changes has been noted and studied by engineers and hydrologists who are analytically inclined and hope to learn more about the

for a more complete interpretation of our empirically founded statistical approaches. It is possible that the 1938 storm of this region approached the maximum possible conditions. Our meteorologist commented with an evaluation of a possible 50 percent of maximum for the widespread type. He added, however, that the March 1938 storm could have been of much longer duration.

Types of Flood Waves

In the southern California coastal area some attention has been brought to frontier hydraulic phenomena which are vaguely understood, if at all. In any event, they are unpredictable to an unsatisfactory degree. The torrential character of the flow from the mountains has exhibited travel or roll waves in both natural and improved channels. The answer to the question of the economic freedom to be used in channel design for such flow is one that engineers now need in order that flows from debris basins may be provided for without waste of public funds or inadvertently presenting a hazard. The travel waves of 1937 observed in the Ventura channel by an engineer for the State of California have not been observed since at stages as high as they were at that time. When existing consideration work is completed and a range of flows are observed, more will be known of their relative importance. It is known that the crest of the roll-waves tend to be dampened in amplitude as the stage of flow is increased in a specific reach of channel and it is hoped that the present design allowances for their development is sufficient.

In natural channels the propagation of the flood wave and the attending configuration changes has been noted and studied by engineers and hydrologists who are analytically inclined and hope to learn more about the

approaches toward the synthetic construction of flood waves for design purposes. Bellasis, an international figure in river hydraulics, made this comment on the phenomenon exhibited in torrential flow from steep catchments: "It largely accounts for flows exceeding those of record. Major waves upstream overtake minor waves of tributaries and cause a great rush at the discharge site." Jerrett Oliver, a district hydrographer for the U. S. Geological Survey, observed travel-waves in the Strawberry Creek channel at Highland Avenue above San Bernardino. They were 2 to 3 feet high travelling on a bed slope of $1\frac{1}{2}$ to 2 percent and moved at 15 to 20 feet per second. They presented a continuous series at intervals of about 10 seconds. Their length was about 650 feet with the latter half nearly a dry bed. A considerable number of engineers have seen the phenomenon in this region and in other areas of the western United States and in a number of foreign countries.

Debris Waves

As noted previously certain debris or mud-rock waves have a consistency of about 40 percent water. The descriptive material available, notably "Flood in La Canada Valley, California, January 1, 1934" by Harold C. Troxell and John Q. Peterson, and in "Flood and Erosion Control Problems and Their Solution" by E. E. Eaton, A.S.C.E. Trans. Vol. 101, pp. 1319-21, 1936, describe the process of the wave progressing downstream by being moved in surface layers; the top being moved forward by waters over-running the wave. Witnesses to the phenomenon in Switzerland, Utah and in southern California describe the type further as follows: This movement is preceded by a squirrel-cage action being crowded from the rear with water from behind occasionally piping through the mass, which moves in the beginning only as

approaches toward the synthesis construction of flood waves for design purposes. Bellas, an international figure in river hydraulics, made this comment on the phenomenon exhibited in horizontal flow from steep embankments: "It largely accounts for flows exceeding those of record. Major waves upstream overtake minor waves of tributaries and cause a great rush at the discharge site." J. Ernest Oliver, a district hydrographer for the U. S. Geological Survey, observed travel-waves in the Strawberry Creek channel at Highland Avenue above San Bernardino. They were 2 to 3 feet high travelling on a bed slope of 1/4 to 2 percent and moved at 15 to 20 feet per second. They presented a continuous series at intervals of about 10 seconds. Their length was about 500 feet with the latter half nearly a dry bed. A considerable number of engineers have seen the phenomenon in this region and in other areas of the western United States and in a number of foreign countries.

Debris Waves

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fast as a man can walk. The waters, which are piped through, and freed of debris, rush ahead and soon dig in and form "pups" as related by Mr. Paul Banman of the Los Angeles County Flood Control District. To continue his description, water gathers and pools behind and if conditions are favorable, the whole mass may accelerate and proceed with great velocity somewhat in the form of an avalanche moving in the stream-bed. These masses often are so plastic that the material on the feather edges on the stream banks near the chaparral is often seen with a roll edge caught among the brush stems with the appearance of a pancake edge or a fairly stiff yet free flowing concrete mix.

Migratory Channel Flows on Cones

Torrential streams debouching on cones, with grades diminishing from 10-12 percent, form fans. The stream is continuously loading and unloading and as it unloads it may take a new course. The entire immediate area along the escarpment trace below the front range mountains is more or less a continuous interlaced cone or series of cones. When real estate developments are advanced on cones and, perhaps, sold to private owners, the disturbances to the freedom of mud-rock and more plastic flows induce the alternating loading and unloading characteristic with great damage to streets, buildings and private property - such as occurred at Rubio Wash. It is this same situation on a larger scale which changed the course of the Los Angeles River from the direct course to Long Beach which was driven through by the flood of 1825. In 1889 the flood followed levied banks through the city, then spread, dropping debris until it veered east to its present course, rejoining its old bed again above the confluence with the Rio Hondo.

least as a man can walk. The waters, which are piped through, and freed of debris, rush ahead and soon dig in and form "pupe" as related by Mr. Paul Hammer of the Los Angeles County Flood Control District. To continue his description, water gathers and pools behind and if conditions are favorable, the whole mass may accelerate and proceed with great velocity somewhat in the form of an avalanche moving in the stream-bed. These masses often are so plastic that the material on the farther edges on the stream banks near the channel is often seen with a roll edge caught among the brush stems with the appearance of a pancake edge or a fairly stiff free flowing concrete mix.

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Historical Stream Course Changes

In addition to the above change of the Los Angeles River east in 1889, several other notable changes have occurred as follows:

1867-68 - The San Gabriel broke from the Rio Hondo on the cone above Whittier Narrows flowing out on the east side to Alamitos Bay.

1884 - The Santa Ana River broke on the cone at the mouth of the Santa Ana Canyon, and, instead of flowing in the usual channel north of the city of Anaheim, flowed to the south of the city in what is now its present channel and forced a new outlet near Newport Beach.

1910-11 - On the San Gabriel cone a major shift occurred, sending much of the flood waters down Lexington Wash, now generally known as the Rio Hondo.

1938 - Rubio Wash, unprotected, reasserted a right-of-way through the highly developed and beautiful Altadena. Lytle Creek at San Bernardino took the old east channel not used since 1884 and overflowed to Mill Street, causing great loss of life and property at E Street and Colton Avenue; \$10,000 damage to the Orange Show. Big Tujunga Wash broke out over the west bank of the Middle Wash at Beck Avenue, completely trenching the street beyond the full width of the roadway, depth 5 feet, causing the curbs to fall in. At Riverside Drive the stream was turned east, trenching the north side of the street and returned to its old channel.

Historical Stream Course Changes

In addition to the above change of the Los Angeles River east in

1887, several other notable changes have occurred as follows:

1887-88 - The San Gabriel broke from the Rio Honda on the cone above

the hills near Whittier Narrows flowing out on the east side to Alamitos Bay.

1884 - The Santa Ana River broke on the cone at the mouth of the

San Gabriel, Santa Ana Canyon, and, instead of flowing in the usual

channel north of the city of Anaheim, flowed to the south

with the result of creating in what is now its present channel and forced

a new outlet near Newport Beach.

1910-11 - On the San Gabriel cone a major shift occurred, sending

much of the flood waters down Lexington Wash, now generally

known as the Rio Honda.

1928 - Rubio Wash, unprotected, traversed a right-of-way through

the highly developed and beautiful Alhambra. Lytle Creek

at San Bernardino took the old east channel and used since

1881, and overflowed to Hill Street, causing great loss of

life and property at E Street and Colton Avenue; \$10,000

damage to the Orange Show, Big Tujunga Wash broke out

over the west bank of the Middle Wash at Beck Avenue,

completely eroding the street beyond the full width of

the roadway, depth 5 feet, causing the cars to fall in.

At Riverside Drive the stream was turned east, eroding

the north side of the street and returning to its old

channel.

Frequency of Floods

The major floods appear to be as follows:

1825	1889	
1833	1890	
1839-40	1911	
1862	1914	14 in 114 years or one in
1867	1916	eight years on the average.
1884	1934	
1886	1938	

The Grange County Flood Report of June 1937 by M. N. Thompson, Chief Engineer to the Board of Supervisors, contains the following:

"The United States Army District Engineers state that from 1771-1936 there occurred 33 serious floods. Adding 1938 totals 34 floods in 168 years or one in five years. Mr. Thompson quotes further, "The flood of the greatest magnitude is that of 1861-2 with 1825 and 1884 nearly as great; 1916 was less than the above."

With respect to 1938, old residents and flood historians state that this flood was definitely greater than those of 1914 and 1916 and compares in peak flows with those of 1884 and 1889 although the floods of 1884 and 1889 were of greater volume because of the duration of the rains.

Recurrence Possibilities

Taking the key from the January 17 and 27 floods of 1916 in San Diego, it is proper to consider 10 days as the planning-time interval of recurrence.

Consideration should be given to the continued rains of 40 days reported for 1839-40 and 1861-2. In such periods, the handling of debris from basins may be delayed unless better equipment is put in use to handle volumes in water.

Frequency of Floods

The major floods appear to be as follows:

1885	1885
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2100	2100

in 111 years or one in eight years on the average.

The Grange County Flood Report of June 1937 by M. N. Thompson,

Chief Engineer to the Board of Supervisors, contains the following:

"The United States Army District Engineers state that from 1771-

1936 there occurred 55 serious floods. Adding 1938 totals 57 floods in 166 years or one in five years. Mr. Thompson quotes further, "The flood of the greatest magnitude is that of 1861-2 with 1885 and 1886 nearly as great; 1916 was less than the above."

With respect to 1938, old residents and flood historians state that this flood was definitely greater than those of 1916 and 1918 and comparable in peak flow with those of 1861 and 1889 although the floods of 1861 and 1889 were of greater volume because of the duration of the rains.

Recurrence Possibilities

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Hazards

Fire is the arch enemy and may ally with a flood. Fire protection facilities and provision for catching and storing water in the mountains should be provided.

Flood (fire accelerated) causes loss of:

1. Vegetal cover
2. Organic matter
3. Soil
4. Water (if adequate impounding dams, diversion, and spreading works are not provided)

Loss and damage to:

- A. Real estate and
- B. Improvements
- C. Property

may be done by flood through the forces of

1. Impact
2. Inundation
3. Sedimentation
4. Undermining

D. Lands

1. Erosion
 - a. Sheet and channel
2. Sedimentation
3. Undercutting and trenching with removal by transportation

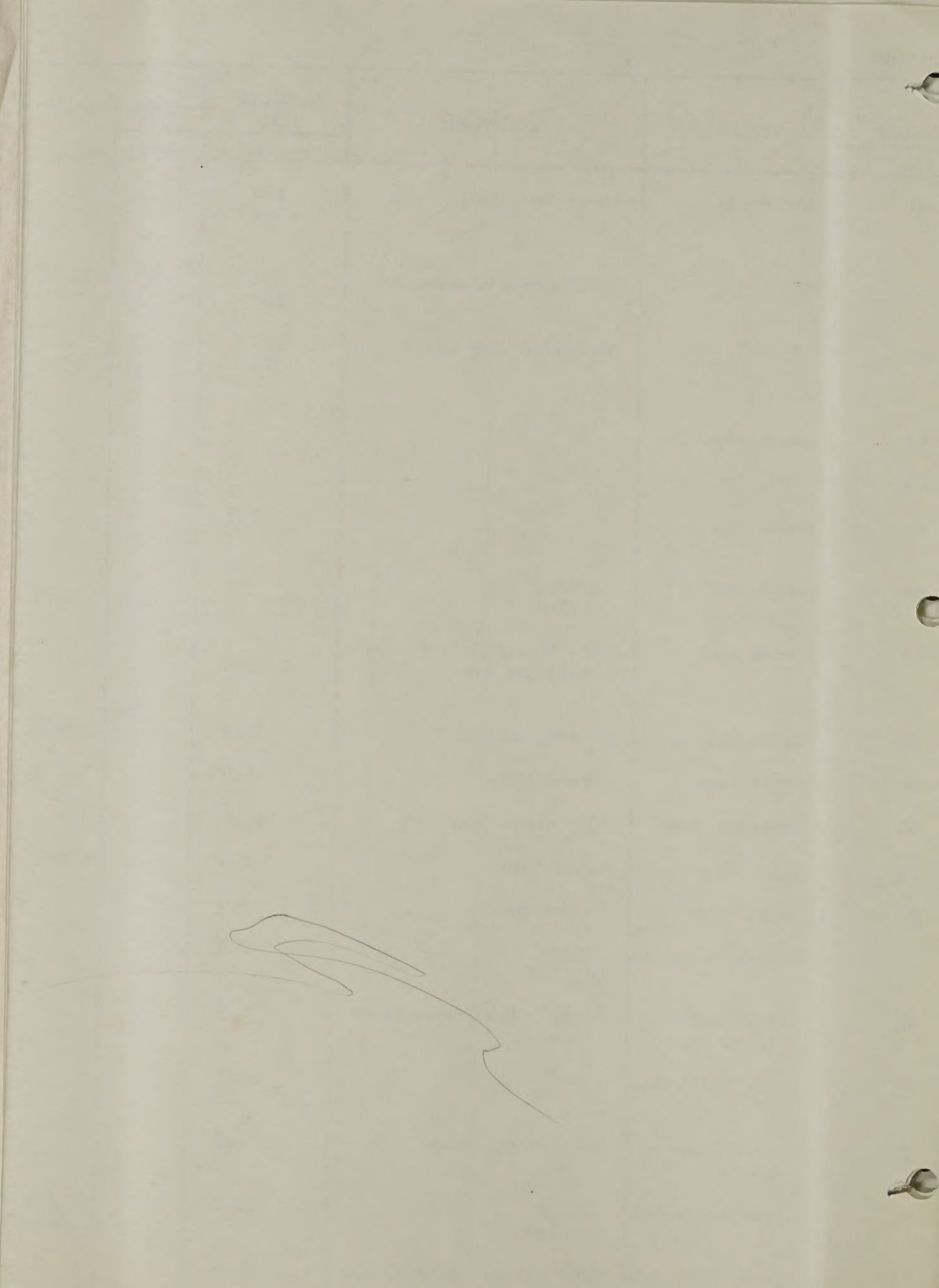
In addition, floods, uncontrolled, bring indirect and intangible damages with threat to life.

FLOOD LOW DATA
March 1938

LOCATION No.	STREAM	LOCATION	DRAINAGE AREA sq. mi.	TENTATIVE, SUBJECT TO CORRECTION MAXIMUM DISCHARGE						SOURCE OR AUTHORITY	REMARKS	RECORD BEGAN year	LENGTH OF RECORD years	PREVIOUS MAXIMUM DISCHARGE					SOURCE OR AUTHORITY
				DATE March	TIME	c.f.s.	c.s.m.	ins.per hr.	MYER					RATIO TO					
									%					m.d.f.					
														DATE	c.f.s.	c.s.m.	ins.per hr.	MYER %	
1	Ventura River	5 mi. No. of Ventura	187			50,000	267	0.42	36.6	U.S.G.S.		1911-14 1929-36	10	12/31/33	23,000	123	0.19	16.8	U.S.G.S.
2	Santa Clara River	4 mi. W. of Saugus	355									1929	6	1/ 1/34	3,870				U.S.G.S.
2a	" "	near Montalvo Bridge	1610			180,000 200,000	112 124	0.18 0.19	45.0 50.0										
3	Sespe Creek	3½ mi. No. of Fillmore	257			66,00	257	0.40	41.0	U.S.G.S.		1911-13 1927-36	13	1/17/16 12/31/33	18,600 34,000	132	0.21	21.2	U.S.G.S.
4	Piru Creek	2 mi. above Jct. Santa Clara River	432			65,000	151	0.24	31.0	U.S.G.S.		1911-13 1927-36	13	1/ 1/34 2/ 9/32	12,000 15,800	37	0.06	7.6	U.S.G.S.
5	Santa Paula Cr.	3 mi. No. of Santa Paula	39.8			10,000	252	0.39	16.0	U.S.G.S.		1927-36	10	12/31/33	10,000	252	0.39	16.0	U.S.G.S.
6	Dume Creek	Roosevelt Highway	8.76									1930	6	12/31/33	2,750				L.A.F.C.D.
7	Malibu Cr.	at Crater Camp	103									1931	5	1/19/33 1/ 1/34	4,460 9,650				L.A.F.C.D.
8	Topanga Cr.	Roosevelt Highway	18									1930	6	12/31/33	4,500				L.A.F.C.D.
9	Ballona Cr.	Sawtelle Blvd.	112	2	9:50 A.	22,500	201	0.31	22.5	L.A.F.C.D.		1928	8	1/ 1/34 4/ 8/35	11,200 11,300				L.A.F.C.D.
10	Centinella Cr.	1.2 mi. So. Jefferson Blvd.	5.17									1932	4	1/ 1/34 3/ 2/35	570 1,590				L.A.F.C.D.
11	Nichols Cr. Dam		.94	2	8:15 A.	260				L.A.F.C.D.				2/18-21 /14	6,480				1915 Ed. F.C. Engineers
12	Nigger Slough	Wilmington Ave.	66									1930	6	1/ 2/34	66				L.A.F.C.D.
13	Aliso Creek	at El Toro	8.5									1930	6	1/ 1/34 2/12/36	1,495 1,420				U.S.C.S.
14	Trabuco Creek	San Juan Capistrano	36.5									1930	6	2/ 8/32 1/ 1/34	381 63				U.S.C.S.
15	San Juan Creek	near San Juan Capistrano	117									1928	8	3/16/30 1/ 1/34	1,230 318				U.S.G.S.
16	San Luis Rey River	Lake Henshaw	209									1911	25	1/27/16	58,600	280			U.S.G.S.
17	" " " "	Pala	383									1935	1	1/27/16	75,000	233			U.S.C.S.
18	" " " "	Bonsall	514									1912-18 1929-36	24	2/25/34	51 128,100	249			U.S.G.S. W.S.P. 447
19	" " " "	Oceanside	565									1912-14, 16 1929-36	11	1934 1/12/16	95,600	169			U.S.G.S.

LOS ANGELES RIVER																				
LOCATION	STREAM	LOCATION	DRAINAGE AREA	TENTATIVE, SUBJECT TO CORRECTION						SOURCE OR AUTHORITY	REMARKS	RECORD BEGAN	LENGTH OF RECORD	PREVIOUS MAXIMUM DISCHARGE				SOURCE OR AUTHORITY		
				DATE	TIME	C.F.S.	c.s.m.	ins.per hr.	MYER					RATIO TO	DATE	c.f.s.	c.s.m.		ins.per hr.	MYER
									%					m.d.f.						%
No.			sq. mi.	March								year	years							
20	Brown Canyon	Devonshire Ave. Chatsworth	14.3									1928-32 1935	7	2/ 9/32	152				L.A.F.C.D.	
21	Los Angeles River	Van Nuys Blvd.	157									1928-36	8	1/ 1/34	7,380				L.A.F.C.D.	
22	" " "	Vineland Ave.	324 402									1930	6	1/ 1/34	9,140				L.A.F.C.D.	
23	" " "	200' below Lankershim Bl.	304											2/18-21 /14	16,780	55			1915 Bd. F.C. Engineers	
24	" " "	200' below filtration galleries	335											2/18-21 /14	24,420	73			Engineers 1915 Bd. F.C.	
25	" " "	Figueroa St., Los Angeles	510			68,000	133	0.21	30.1		L.A.F.C.D.	1929	7	1/ 1/34	22,000				L.A.F.C.D.	
26	" " "	below Main St. bridge	534											2/18-21 /14	31,140	58			1915 Bd. F.C. Engineers	
27	" " "	So. Pacific crossing												12/24/ 1889	41,250 50,000				H. Hawgood Wm. Mulholland	
28	" " "	Stewart & Grey Rd.	614			70-80,000	130	0.20	30.2		L.A.F.C.D.	1928	8	1/ 1/34	29,400				L.A.F.C.D.	
29	" " "	State St., Long Beach	923 1038	2	9:00 P.	102,000	105	0.16	32.7		L.A.F.C.D.	1931	5	1/ 1/34	37,500				L.A.F.C.D.	
30	Pacoima Dam , Inflow " " , Outflow		27.77	2	4:30 P.	6,400 2,400			12.1		L.A.F.C.D.									
31	Little Tujunga Cr.	Foothill Blvd.	21									1928	8	1/ 1/34	1,360				L.A.F.C.D.	
32	Big Tujunga Cr.	above Edison Road	67									1932	4	2/ 8/32 1/ 1/34	3,910 1,520				L.A.F.C.D.	
33	Big Tujunga Dam	Big Tujunga Canyon	81.35			36,000	467 443	0.73 0.69	42 40		L.A.F.C.D.									
34	" " "	below submerged dam near Sunland	106									1916	20	12/19/21 1/ 1/34	8,500 1,450				L.A.F.C.D.	
35	" " Cr.		118											2/18-21 /14	13,600				1915 Bd. F.C. Engineers	
36	" " Wash	at Stonehurse Ave.	148									1932	4	1/ 1/34	3,750				L.A.F.C.D.	
37	" " West "	at Magnolia Blvd.	88 167									1930	6	1/ 1/34	145				L.A.F.C.D.	
38	" " East "	at Chandler Blvd.	83 162									1936								

LOS ANGELES RIVER (cont'd)				FLOOD FLOW DATA										March 1938				page 3		
LOCATION No.	STREAM	LOCATION	DRAINAGE AREA sq. mi.	TENTATIVE, SUBJECT TO CORRECTION MAXIMUM DISCHARGE						SOURCE OR AUTHORITY	REMARKS	RECORD BEGAN year	LENGTH OF RECORD years	PREVIOUS MAXIMUM DISCHARGE					SOURCE OF AUTHORITY	
				DATE March	TIME	c.f.s.	c.s.m.	ins. per hr.	MYER					RATIO TO	DATE	c.f.s.	c.s.m.	ins. per hr.		MYER
									%					m.d.f.						%
56	Arroyo Seco Cr.	at Devil's Gate	30.62											2/18-21/ 1914	11,400	372		21	1915 Bd. F.C. Engineers	
57	Arroyo Seco	at Colorado St. Bridge	38.6											2/18-21/ 1914	14,136	366			1915 Bd. F.C. Engineers	
58	" "	San Pasqual Ave.	42.7											2/18-21/ 1914	7,610	178			1915 Bd. F.C. Engineers	
59	" "	near Avenue 36	49.5											2/18-21/ 1914 1/17/16	5,880 6,215	119			1915 Bd. F.C. Engineers	



LOCATION No.	STREAM	LOCATION	DRAINAGE AREA sq.mi.	TENTATIVE, SUBJECT TO CORRECTION MAXIMUM DISCHARGE						SOURCE OR AUTHORITY	REMARKS	RECORD BEGAN year	LENGTH OF RECORD years	PREVIOUS MAXIMUM DISCHARGE				SOURCE OR AUTHORITY		
				DATE March	TIME	c.f.s.	c.s.m.	ins.per hr.	MYER					RATIO TO	DATE	c.f.s.	c.s.m.		ins.per hr.	MYER
									%					m.d.f.						%
60	Rio Hondo	Lower Azusa Rd.	170 285			28,000						1932	4	1/ 1/34	5,860				1915 Bd. F.C. Engineers	
61	" "	1000' above Mission Br.	228 343	2	11:00 P.	130,000 850,000				L.A.F.C.D.		1931	5	1/ 1/34	11,800				1915 Bd. F.C. Engineers	
62	" "	Stewart-& Grey Rd.	255 370			30,000				L.A.F.C.D.		1928	8	2/18-21/ 1914 1/ 1/34	20,930 16,000				1915 Bd. F.C. Engineers	
63	Las Flores Cr.																			
64	Rubio Cr.																			
65	Eaton Cr.		6.5									1918-36	18	4/ 7/26 1/ 1/34	1,360 330				U.S.G.S.	
66	Eaton Dam	Inflow Outflow		2	3:05 P.	2,300				L.A.F.C.D.										
67	Eaton Wash	Bet. Foothill Blvd. and S.F. Ry. Br.	12.5											2/18-21/ 1914	4,590	367	0.57	13	F.C. Board L.A. 1915	
68	Eaton Wash	Huntington Dr.	12.9	2	4:15 P.	3,600				Pasadena Water Dept										
69	Eaton Wash	Sunset Ave.	18.4																	
70	Alhambra Wash	250' above Short St.	14.5									1930	6	1/ 1/34	4,890				1915 Bd. F.C. Engineers	
71	Rubio Wash	Roses Road	10.4	2	8:45 A.	2,200				Pasadena Water Dept										
72	Rubio Wash	at Broadway	13.0									1930	6	12/31/33	2,070				L.A.F.C.D.	
73	Sierra Madre Dam	Inflow Outflow	2.39																	
74	Little Santa Anita Cr.	1/4 mi. below Sierra Madre Dam	2.57									1929-36	7	12/31/33 1/19/33	39 90					
75	Santa Anita Cr.	above dam	10.5									1916	20	4/ 7/26 1/ 1/34	2,800 564				U.S.G.S.	
75a	Little Santa Anita	near Sierra Madre	1.9									1916-25 1926-34	17	4/ 7/26 12/31/33	5.4.11.75 89				U.S.G.S.	
76	Santa Anita Dam	Inflow Outflow	10.82	2 2	4:20 P. 4-4:30	4,900 4,400	453	0.71	15	L.A.F.C.D. L.A.F.C.D.										
77	Santa Anita Wash	500' No. of Foothill Rd.	18.2											2/18-31/ 1914	3,168 399				1915 Bd. F.C. Engineers	

LOCATION		STREAM	LOCATION	DRAINAGE AREA	TENTATIVE, SUBJECT TO CORRECTION MAXIMUM DISCHARGE						SOURCES OR AUTHORITY	REMARKS	RECORD BEGAN	LENGTH OF RECORD	PREVIOUS MAXIMUM DISCHARGE				SOURCES OR AUTHORITY		
				sq.mi.	DATE	TIME	c.f.s.	c.s.m.	ins. per hr.	MYER %	RATIO TO m.d.f.					DATE	c.f.s.	c.s.m.	ins. per hr.	MYER %	
					March								year	years							
78	Santa Anita Wash	below Arrow Highway	21.1										1932-36	4	2/18-21/ 1914	3,168 399					L.A.F.C.D.
79	Monrovia Cr.	200' above jet. Sawpit	1.9				527		.82				1927	9	1/ 1/34 4/8 /35	108 109					1915 Bd. F.C. Engineers
80	Monrovia Storm Drain	near Peck Rd.	4.47				448		.70				1932	4	1/ 1/34	554					1915 Bd. F.C. Engineers

LOCATION No.	STREAM	LOCATION	DRAINAGE AREA sq.mi.	TENTATIVE, SUBJECT TO CORRECTION MAXIMUM DISCHARGE						SOURCE OR AUTHORITY	REMARKS	RECORD YEARS year	LENGTH OF YEARS years	PREVIOUS MAXIMUM DISCHARGE					SOURCE OR AUTHORITY
				DATE	TIME	c.f.s.	c.s.m.	ins. per hr.	MYER %	RATIO TO m.d.f.				DATE	c.f.s.	c.s.m.	ins. per hr.	MYER %	
				March															
81	San Gabriel River	3 $\frac{1}{2}$ miles above Dam #2	14.4									1933	3	1/ 1/34	1,850				L.A.F.C.D.
82	" "	Dam #2	40.42	2	4:25 P.	23,000	568	0.89	36.2		L.A.F.C.D.								
				2	5:00 P.	21,500			33.8										
83	" "	West Fork, $\frac{1}{2}$ mi. below Dam #2	40.8									1932	4	1/ 1/34	4,400				L.A.F.C.D.
84	" "	West Fork, 2 mi. above Forks	102.									1930	6	1/ 1/34	5,320				L.A.F.C.D.
85	" "	East Fork, " "	91.41									1932	4	1/ 1/34	8,500				L.A.F.C.D.
86	" "	Dam #1	202.	2	4:00 P.	95,000			67.		L.A.F.C.D.								
				2	7:15 P.	56,300					L.A.F.C.D.								
87	" "	Morris Dam	210.9	2	6:08 P.	66,400					Pasadena Water Dept.								L.A. Co. Bd. of Superv.
				2	7:06 P.														
				2	7:12 P.	65,300													
88	" "	near Azuda	214									1894	42	1/18/16	40,000				U.S.G.S.
														1/ 1/34	6,120				
88a	" "	Cr.												1889	47,000				H. Harwood Barker
89	" "	River below mouth of Rogers Cr.	226.7												26,680	117	0.18	18	1915 Bd. F.C. Engineers
90	" "	Foothill Blvd.	230	2	7:35 P.	43,000					L.A.F.C.D.								
91	" "	Easy St.																	
92	" "	Spring St.	327 442			32,000					L.A.F.C.D.								
93	" "	Devils Cr. 2 mi. above Dam #2	15.4									1933	3	1/ 1/34	1,560				L.A.F.C.D.
94	" "	Bear Cr., Boy Scout Camp	26									1929	7	1/ 1/34	1,600				L.A.F.C.D.
95	" "	" " , 500' above West Fork	27.9									1935	1	2/12/36	410				L.A.F.C.D.
96	" "	North Fork, .7 mi. above mouth	18.8									1929	7	1/ 1/34	276				L.A.F.C.D.
97	Sawpit Cr. Dam	Inflow	3.27																
		Outflow																	
98	" "	near Monrovia	5.3									1916	20	1/ 1/34 4/ 7/36	350 2,000				U.S.G.S.

[illegible]

FLOOD FLOW DATA

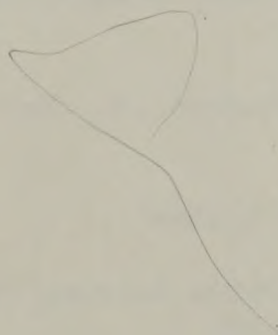
March 1938

SANTA ANA RIVER

LOCATION No.	STREAM	LOCATION	DRAINAGE AREA sq. mi.	TENTATIVE, SUBJECT TO CORRECTION MAXIMUM DISCHARGE							SOURCE OR AUTHORITY	REMARKS	RECORD BEGAN year	LENGTH OF RECORD years	PREVIOUS MAXIMUM DISCHARGE					SOURCE OR AUTHORITY				
				DATE March	TIME	c.f.s.	c.s.m.	ins. per hr.	MYER	RATIO TO														
									%	m.d.f.														
																			DATE	c.f.s.	c.s.m.	ins. per hr.	MYER %	
107a	San Antonio Cr.	above head gates	28			20,000	714	1.11	38			Ward	1931	5	2/8-9/32 1/ 1/34	405 119			U.S.G.S.					
108a	Cucamonga Cr.	above #4 crosswall	10.1	2	4:00 P.	6,000	594	.93	19			Ward	1928	8	12/31/33 2/11/36	313 475								
109a	Deer Cr.																							
110	Day Cr.	6 mi. No. near Etiwanda	4.8										1929	7	1/ 1/34 2/11/36	84 192			U.S.G.S.					
111	Lytle Cr.	near Fontana	47.9	2	3:30 P. 5:00 P.	29,000	605	.95	42			Major P. B. Hasbrouck	1918		2/16/27 1/ 1/34	5,300 560			U.S.G.S.					
112	" "	Elison Power Pl.		12	2:00 P.	30,000						Phoned to Forester												
113	" "	E. Channel San Bernardino	40												2/ 9/32 1/ 1/34	700 555								
114	" "	at San Bernardino	140												2/23/91 1/ 1/34	30,020 555	214	0.34	25 U.S.G.S. WSP 447					
115	Lone Pine	near Keenbrook	15.3												12/19/21 1/ 1/34	810 270								
116	Cajon Cr.	Keenbrook, Calif.	40.9			10,000			16			Oliver , U.S.G.S.			12/20/21 1/ 1/34	5,000 570								
117	" "	near Devore													2/20/14	8,360			U.S.G.S. WSP 447					
118	Devil Cr.	7.3 mi. No. of S. B.	6.16	2	3:00 P.								1920	16	4/ 7/26 1/ 1/34	220 56			U.S.G.S.					
119	Strawberry Cr.	near Arrowhead Springs	8.6										1920	16	1/ 2/22 1/ 1/34	408 240								
120	City Cr.	at Highland	19.8										1919	17	4/ 5/26 1/ 1/34	2,360 374			U.S.G.S. WSP 447					
121	Plunge Cr.	at E. Highlands	16.9										1919	17	2/16/27 12/31/33	1,420 380			U.S.G.S. WSP 447					
122	Waterman Cr.	near Arrowhead Springs	4.55										1912-14 1921-36	18	12/31/33 2/ 2/36	114 182			U.S.G.S. WSP 447					
123	Mill Cr.	Craftonville	42.9	2	7-10:00 P.	20,000			31			Geo. Hinckley	1919-36	17	2/16/27 1/ 1/34	4,500 328								
124	Wana Cr.	near Colton	50.	2	7-10:00 P.	30,000			42			Geo. Hinckley	1920	16	12/21/21 1/ 1/34	2,780 930			U.S.G.S.					

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FLOOD FLOW DATA																				
LOCATION	STREAM	LOCATION	DRAINAGE AREA	TENTATIVE, SUBJECT TO CORRECTION MAXIMUM DISCHARGE						SOURCE OR AUTHORITY	REMARKS	RECORD BEGAN	LENGTH OF RECORD	PREVIOUS MAXIMUM DISCHARGE				SOURCE OR AUTHORITY		
				DATE	TIME	c.f.s.	c.s.m.	ins. per hr.	MYER					RATIO TO	DATE	c.s.f.	c.s.m.		ins. per hr.	MYER
				March					%					m.d.f.						%
			sq. mi.									year	years							
125	San Jacinto River	near San Jacinto	140											2/16/27 1/ 1/34	45,000 295			U.S.G.S.		
126	" " "	near Elsinore	718			2,500			1	Oliver, U.S.G.S.				2/17/27 1/ 1/34	16,000					
127	Elsinore Lake	at Elsinore	764																	
128	San Tinoteo Cr.	near Redlands	118			6,000 7,000			6			1926	10	2/16/27 12/31/33	3,000 150					
129	Temescal Cr.	near Corona above Cojales Cr.	926									1929	7	2/23/91	27,420			U.S.G.S. WSP 447		
130	Chino Cr.	near Prado										1929	7	1/1/34	1,440			U.S.G.S.		
131	Santiago Reservoir		63									1932	4							
132	" Cr.	near Villa Cr.	83.8											2/16/27 1/ 1/34	11,000 271					
133	" "	at Santa Ana										1929	7	12/28/31	272			U.S.G.S.		
134	Hagador Tin Mine Cns.	near Corona				2,500				C.A.Davidson Forest Service Rpt.										
135	Irvine Ranch	near Tustin	93									1930	6	1/19/33 1/ 1/34	4,330 3,000			U.S.G.S.		
136	Big Bear Lake																			
137	Santa Ana	near Mentone	189			45,000	238		33	Geo. Hinckley		1896	40	1/27/16 12/31/33	29,100 1,880			U.S.G.S.		
138	" "	Redlands, Orange, San Br.				45,000				Geo. Hinckley (Oliver)										
139	" "	Tippacance St., San Berd.	290			50,000	172	29		Jarrett Oliver		1928	8	1/17/16 1/ 1/34	40,000 744			U.S.G.S.		
140	" "	near Colton				80,000 82,000 - 93,000														
141	" "	Riverside Narrows, Pedley Bridge	705	2	10:15 P 11:15 P.		132	31 35		A. C. Fullmore		1929	7	12/21/31 1/ 1/34	4,740 1,820			U.S.G.S.		
142	" "	Prado	2288	3	12:15 A.	106,500	47	22		U.S.G.S.		1919	17	2/16/27 1/ 1/34	18,000 3,300			U.S.G.S.		

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APPENDIX II

Section 3.

- a. Sedimentation of reservoirs and channels, etc. - Don A. Johnson
- b. Deposition of debris and silt on agricultural lands, etc. -
Don A. Johnson
- c. Report on flood damage survey in San Gabriel, Little Dalton,
Big Dalton, San Dimas and San Antonio Watersheds - W. T. Corum
- d. Watershed erosion, forest vegetation, and burned areas-
C. H. Gleason
- e. Reconnaissance of road damage in mountain watersheds of southern
California - D. M. Ilch

APPENDIX II

Section 3a and b

SEDIMENTATION OF RESERVOIRS AND CHANNELS
AND
DEPOSITION OF DEBRIS AND SILT
ON
AGRICULTURAL AND URBAN AREAS

By

Don A. Johnson
Soil Conservation Service

APPENDIX II
Section 7e and 7f

REGULATION OF RECREATION AND COUNTRY
AND
DEVELOPMENT OF RECREATION AND COUNTRY
ON
AGRICULTURAL AND URBAN AREAS

By
Hon. A. Johnston
Soil Conservation Service

SEDIMENTATION RESULTING FROM THE
STORM OF MARCH 2, 1938

This chapter includes data on various types of sedimentation which could be compiled prior to March 19, 1938. The data were obtained from state, county, city and private agencies, including flood control districts and agricultural commission. Surveys are now under way on flood plains lands and reservoirs to determine more accurately the amount of debris deposition and the extent of damage resulting from it. Damage by debris in this flood was one of the most serious forms of flood loss and accounts for a very appreciable part of the total flood damage.

The following estimates were supplied on the basis of very incomplete data and should be considered highly tentative. The included table summarizing debris damages available at the time shows the magnitude of deposits and losses resulting therefrom, but when more complete information is available the losses will undoubtedly be found to be much greater than indicated here.

SEDIMENTATION RESULTING FROM THE

STORM OF MARCH 2, 1933

This chapter includes data on various types of sedimentation which could be compiled prior to March 12, 1933. The data were obtained from state, county, city and private agencies, including flood control districts and agricultural commissions. Surveys are now under way on flood plain lands and reservoirs to determine more accurately the amount of debris deposited and the extent of damage resulting from it. Damage by debris in this flood was one of the most serious forms of flood loss and accounts for a very appreciable part of the total flood damage.

The following estimates were supplied on the basis of very incomplete data and should be considered highly tentative. The included table summarizing debris damage available at the time shows the amount of deposits and losses resulting therefrom, but when more complete information is available the losses will undoubtedly be found to be much greater than indicated here.

Sedimentation in Storage Reservoirs

Reservoirs for flood control and conservation storage suffered tremendous capacity losses as a result of this flood. As yet, little quantitative data have been obtained on the extent of losses but inspections of the reservoirs reveal extensive delta accumulations of coarse debris extending far down into the reservoirs, and a few soundings have indicated widespread accumulations of 10 to 70 feet of debris in typical reservoirs in the one week of heavy runoff. In Los Angeles County, where the only available data are thus far available, 17 reservoirs for flood control, water conservation, and debris storage have been constructed at a total cost of approximately \$21,000,000. Observations thus far made on each of these are given below:

Big Dalton: Survey under way. No data available as yet. Original cost \$1,020,525.

Devil's Gate: Soundings made since the flood show 16 feet additional accumulation at the dam and 25 to 26 feet of accumulation in the upper part of the reservoir. No volumetric estimates are yet available.

The Angeles Highway, 11 to 12 miles long within the watershed, is reported to have contributed much debris. Data furnished by the Los Angeles County Flood Control District show that this reservoir had a capacity, in 1916, of 4608 feet to spillway crest and a flood storage capacity of 6518 acre feet to the maximum high water line. In September 1934 the capacity at Spillway was 4144 acre feet and 47 acre feet of sediment had been removed, making the total silt accumulation 511 feet or 11.1 percent of the original capacity.

Sedimentation in Storage Reservoirs

Reservoirs for flood control and conservation storage suffered tremendous capacity losses as a result of this flood. As yet, little quantitative data have been obtained on the extent of losses but inspection of the reservoirs reveal extensive delta accumulations of coarse debris extending far down into the reservoirs, and a few soundings have indicated widespread accumulations of 10 to 70 feet of debris in typical reservoirs in the west of heavy runoff. In Los Angeles County, where the only available data are thus far available, if reservoirs for flood control, water conservation, and debris storage have been constructed at a total cost of approximately \$21,000,000. Operations thus far made on each of

these are given below:

Big Dalton: Survey under way. No data available as yet. Original

cost \$1,020,325.

Devlin's Lake: Soundings made since the flood show 10 feet additional accumulation at the dam and 25 to 35 feet of accumulation in the upper part of the reservoir. No quantitative estimates are yet available.

The Angeles Highway, 11 to 12 miles long within the watershed, is reported to have contributed much debris. Data furnished by the Los Angeles County Flood Control District show that this reservoir had a capacity, in 1916, of 1,600 feet of spillway cross and a flood storage capacity of 6,218 acre feet to the maximum high water line. In September 1928 the capacity at spillway was 1,114 acre feet and 17 acre feet of sediment had been removed, making the total sill accumulation 511 feet or 11.1 percent of the original capacity.

In the storm of October 1934, 137 acre feet, in addition were lost during a runoff of 480 acre feet. The sediment load brought in by this storm represented 28.6 percent of the total inflow. Making an assumption based on the above data that the total accumulation from October 31, 1934 to February 26, 1938 was 120 acre feet, the total fill to the later date was 768 acre feet or 16-2/3 per cent of the original capacity. Excluding sediment removed, the reservoir probably had 700 acre feet of accumulation at the beginning of this storm. Study of data for debris basins and other reservoirs suggest that possibly 1200 acre feet of debris were brought into Devil's Gate Reservoir. This amount represents about one quarter of the original capacity or a damage during this storm in the neighborhood of \$120,000. Original cost of this reservoir was \$483,943.

Eaton Wash: Soundings have been made since the flood but data are not yet available.

Live Oak: No soundings have yet been made. An accurate survey made in March 1936 by the Soil Conservation Service showed 292 acre feet capacity as of that date. Original cost \$185,663.

Morris Dam: Officials of the City of Pasadena estimate that this reservoir, built by Pasadena in 1932 at a cost of \$7,600,00 with 39,300 acre feet original capacity, lost 2000 acre feet of storage because of debris accumulation during this storm. This represents 5 percent of the original capacity, or based on a depreciation proportional to storage loss, a damage of \$380,000.

In the storm of October 1931, 137 acre feet, in addition were lost during a runoff of 180 acre feet. The sediment load brought in by this storm represented 20.6 percent of the total inflow. Making an assumption based on the above data that the total accumulation from October 31, 1931 to February 26, 1932 was 120 acre feet, the total fill to the lower dam was 765 acre feet or 16.2% per cent of the original capacity. Excluding sediment removed, the reservoir probably had 700 acre feet of accumulation at the beginning of this storm. Study of data for debris basins and other reservoirs suggests that possibly 1200 acre feet of debris were brought into Leavitt's Lake Reservoir. This amount represents about one quarter of the original capacity or a damage during this storm in the neighborhood of \$120,000. Original cost of this reservoir was \$485,000.

Station Wash: Soundings have been made since the flood but data are not

yet available.

Live Oak: No soundings have yet been made. An accurate survey made in

March 1936 by the Soil Conservation Service showed 325 acre

foot capacity as of that date. Original cost \$155,000.

Hortie Dam: Officials of the City of Pasadena estimate that this reservoir,

built by Pasadena in 1925 at a cost of \$7,600,000 with

57,300 acre foot original capacity, lost 2000 acre feet of

storage because of debris accumulation during this storm.

This represents 5 percent of the original capacity, or

based on a depreciation proportional to storage loss, a

damage of \$380,000.

Pacoima

No soundings have been made since the storm as the reservoir is still inaccessible. The Los Angeles County Flood Control District reports that soundings in 1934 showed that, in the previous five years, 71 feet of silt had accumulated just above the dam, including debris brought in by the January 1934 storm. Original Cost \$2,466,738.

Puddingstone

Probably less silting occurred in this basin than in any other since it receives most of its flow by diversion rather than by direct runoff. It is situated below San Dimas and Puddingstone diversion dams on San Dimas Creek. A reconnaissance examination in the spring of 1936 indicated that the reservoir had filled about 1.5 per cent in 8 years. Original cost \$1,021,618.

Puddingstone Diversion

A capacity survey of this reservoir, made in 1936, showed that it had 52.74 acre feet of storage to elevation 1146.2 (Valve #2 - 5) and 121.17 acre feet to elevation 1153.2 or spillway crest. The capacities at these elevations since the storm are estimated as 0.61 and 43.16 acre feet respectively, representing 99 per cent and 65 per cent depletion of storage at these elevations. Original cost \$185,325.

San Dimas

No surveys have been made since the flood. Original cost \$589,860.

No soundings have been made since the storm as the reservoir is still inoperative. The Los Angeles County Flood Control District reports that soundings in 1936 showed that, in the previous five years, 71 feet of silt had accumulated just above the dam, including debris brought in by the January 1934 storm.

Original cost \$2,466,738.

Redding Dam

Probably less siltage occurred in this basin than in any other since it receives most of the flow by diversion rather than by direct runoff. It is situated below San Dimas and Redding dams on San Dimas Creek. A reconnaissance examination in the spring of 1936 indicated that the reservoir had filled about 1.5 per cent in 5 years. Original cost \$1,021,618.

Redding Dam Diversion

A capacity survey of this reservoir, made in 1936, showed that it had 52.74 acre feet of storage at elevation 1154.2 (Valve 2 - 5) and 121.17 acre feet at elevation 1155.2 or spillway crest. The capacities at these elevations since the storm are estimated as 0.61 and 15.16 acre feet respectively, representing 99 per cent and 65 per cent depletion of storage at these elevations. Original cost \$165,355.

San Dimas

No surveys have been made since the flood. Original cost \$289,860.

San Gabriel No. 2

No soundings have yet been made. It is reported that a large amount of quarry waste was moved down into the reservoir area in Devil's Canyon. Original cost \$3,127,761.

San Gabriel No. 1

No soundings have yet been made. It is reported that the high water line was moved $\frac{1}{2}$ mile down the reservoir by coarse debris accumulation.

Santa Anita

A detailed sedimentation survey of this reservoir, made by the Soil Conservation Service in February 1936, showed that since previous mapping March 1928, it had lost 3.63 per cent of its original capacity of 1048 acre feet in 8.9 years. The total accumulation in this period was 38 acre feet

Preliminary calculation in one week amounted to 54,500 cubic yards per square mile of watershed or a total of approximately 360 acre feet. This represents a loss of about $3\frac{1}{2}$ per cent of the original storage capacity or almost 10 times as much from this one storm as from the total accumulation of the preceding 10 years. Based on a uniform depreciation in the original cost of \$1,207,885 this represents a loss of \$416,720 for this reservoir during the storm.

No soundings have yet been made. It is reported that a large amount of quarry waste was moved down into the reservoir area in Devil's Canyon. Original cost \$3,127,761.

No soundings have yet been made. It is reported that the high water line was moved $\frac{1}{2}$ mile down the reservoir by coarse debris accumulation.

A detailed sedimentation survey of this reservoir, made by the Soil Conservation Service in February 1936, showed that since previous mapping March 1923, it had lost 5.65 per cent of its original capacity of 1043 acre feet in 13.9 years. The total accumulation in this period was 30 acre feet.

Preliminary calculation in one week amounted to \$1,800 cubic yards per square mile of watershed or a total of approximately 300 acre feet. This represents a loss of about $\frac{1}{10}$ per cent of the original storage capacity or almost 10 times as much from this one storm as from the total accumulation of the preceding 10 years. Based on a uniform deposition in the original cost of \$1,207,885 this represents a loss of \$146,720 for this reservoir during the storm.

Sawpit

Soundings by the Los Angeles County Flood Control District showed that this reservoir lost approximately 2.2 per cent of its 1927 capacity of 476 acre feet in the 8 years ending in 1935. If the rate of debris production during the 1938 storm was as large in this watershed as in the adjoining Santa Anita watershed, the reservoir probably lost about 23 per cent of its original capacity in this storm. The monetary loss involved in a 23 per cent capacity reduction would be \$146,527 on the original cost of \$637,075.

Sierra Madre

This reservoir was completed in February 1928, at a cost of \$68,229, for flood control and debris storage and had an original capacity of 49.49 acre feet to spillway elevation 1172.5. Surveys in 1930 and 1932 showed that it had capacities of 48.68 acre feet and 47.40 acre feet, representing losses of .79 acre foot and 1.28 acre foot, respectively at those dates. Soundings since the 1938 storm show that only 5.42 acre feet of storage is left. Assuming that the silting rate to the date of this storm was uniform, the loss in this one storm may be estimated as 36 acre feet or 77 per cent of the original capacity.

Since 1932, 85,000 cubic yards of debris have been moved down the little Santa Anita Canyon to below elevation 1202, which is 23 feet above the top of the dam and 29.5 feet above spillway elevation. Of this amount, 17,000 cubic yards is still above spillway elevation 1172.5. This is far more than enough to fill up the remaining storage capacity of 5.42 acre feet. This watershed has suffered no major burn since 1900 and has not been touched in any part by fire since 1920 when a very small spot was burned. Original cost \$68,229.

Roundings by the Los Angeles County Flood Control District

showed that this reservoir lost approximately 2.2 per cent of its 1937 capacity of 17.5 acre feet in the 3 years ending in 1940. If the rate of debris production during the 1938 storm was as large as this watershed as in the adjoining Santa Anita watershed, the reservoir probably lost about 2.5 per cent of its original capacity in this storm. The monetary loss involved in a 2.5 per cent capacity reduction would be \$146,327 on the original cost of \$585,329.

State Lake

This reservoir was completed in February 1928, at a cost of \$65,329, for flood control and debris storage and had an original capacity of 15.49 acre feet to spillway elevation 1172.5. Surveys in 1930 and 1938 showed that it had capacities of 15.58 acre feet and 17.10 acre feet, representing losses of .79 acre foot and 1.52 acre foot, respectively at those dates. Roundings since the 1938 storm show that only 2.49 acre feet of storage is left. Assuming that the filling rate to the date of this storm was uniform, the loss in this one storm may be estimated as 3.6 acre feet or 7.7 per cent of the original capacity.

Since 1938, 85,000 cubic yards of debris have been moved down the little Santa Anita Canyon to below elevation 1202, which is 25 feet above the top of the dam and 22.5 feet above spillway elevation. Of this amount, 17,000 cubic yards is still above spillway elevation 1172.5. This is far more than enough to fill up the remaining storage capacity of 2.49 acre feet. This watershed has suffered no major burn since 1900 and has not been touched in any part by fire since 1920 when a very small spot was burned. Original cost \$65,329.

Sunset Canyon

This reservoir built for flood control and debris storage is estimated to have received 8 to 10 thousand cubic yards of debris during this flood and is now nearly full. Its original debris capacity to the dam crest was 32,000 cubic yards, but much debris was in the reservoir at the time of the flood. Original cost \$30,848.

Thompson Creek

No data are available. Original cost \$252,629.

Big Tujunga No. 1

Soundings have been made since the flood but data are not available. It is reported that debris shifted the head of backwater far down into the reservoir to a point below Fox Creek. Original cost \$1,166,916.

This reservoir built for flood control and debris storage is estimated to have received 8 to 10 thousand cubic yards of debris during this flood and is now nearly full. The original debris capacity to the dam crest was 32,000 cubic yards, but much debris was in the reservoir at the time of the flood. Original cost \$70,250.

Thompson Creek

No data are available. Original cost \$225,000.

Big Tanager No. 1

Soundings have been made since the flood but data are not available. It is reported that debris shifted the head of the reservoir far down into the reservoir to a point below Fox Creek. Original cost \$1,166,916.

Los Angeles County Flood Control District

ESTIMATES ON STORM OF MARCH 2, 1938

March 15, 1938

ESTIMATED AMOUNTS OF DEBRIS DEPOSITED IN DEBRIS
BASINS FROM FEBRUARY 28 TO MARCH 3, 1938

The following explanatory comments are given relative to the data on debris deposition in the accompanying table:

Maximum Debris Capacity: The quantities given in this column were based upon the assumption that the maximum debris capacity of each basin would be that deposited on a uniform grade line between the spillway sill and the floor at the top of the inlet structure. At both Pickens and Hall-Beckley Debris Basins, the debris was deposited on a slope of sufficient steepness to exceed the original maximum quantities.

Estimated Volume of Debris in Basins March 3: The volumes appearing in this column are the estimated percentages of maximum debris capacity which were attained during the storm. The exceptions to this statement are those quantities followed by 1/ which quantities were obtained from field surveys made immediately after the storm.

The quantities given for Pickens and Hall-Beckley Debris Basins do not include a considerable volume of debris which was deposited in the channel upstream from the inlet structure of these two basins, due to the steepness of the debris deposition gradient upstream from the spillway sill. Pickens Debris Basin deposition at the top of the inlet structure was 12 feet deep, while that at the top of the inlet structure at Hall-Beckley Debris Basin was approximately 8 feet deep.

At Pickens, Hall-Beckley, Dunsmuir, Verdugo, Lincoln and Las Flores Basins an indeterminate volume of debris passed over the spillways of these structures during the peak inflow periods, so that the total volume eroded from the individual watersheds are in excess of the figures given.

Estimated Volume of Debris in Basins Prior to Feb. 28: Volumes given in this column are based upon estimated observed quantities deposited in the various debris basins up to February 27. In some cases the basins had been recently cleaned out, and in other cases relatively little deposition had occurred since their construction.

The last three columns are self-explanatory.

ESTIMATES ON STORM OF MARCH 2, 1938

March 15, 1938

ESTIMATED AMOUNTS OF DEBRIS DEPOSITED IN BASINS
BASED ON PHOTOGRAPHY OF MARCH 2, 1938

The following explanatory comments are given relative to the

data on debris deposition in the accompanying table:

Maximum Debris Quantity: The quantities given in this column were based upon the assumption that the maximum debris quantity of each basin would be that deposited on a uniform grade line between the spillway sill and the floor of the inlet structure. At both Lincoln and Hall-Beckley Debris Basins, the debris was deposited on a slope of sufficient steepness to exceed the original maximum quantities.

Estimated Volume of Debris in Basin March 2: The volumes appearing in this column are the estimated percentages of maximum debris capacity which were obtained during the storm. The assumptions in this statement are those quantities followed by 1 which quantities were obtained from field surveys made immediately after the storm.

The quantities given for Lincoln and Hall-Beckley Debris Basins do not include a considerable volume of debris which was deposited in the channel upstream from the inlet structure of these two basins, due to the steepness of the debris deposition gradient upstream from the spillway sill. Lincoln Debris Basin deposition at the top of the inlet structure was 12 feet deep, while that at the top of the inlet structure at Hall-Beckley Debris Basin was approximately 8 feet deep.

At Lincoln, Hall-Beckley, Bunkerhill, Verdugo, Lincoln and San Flores Basins an indeterminate volume of debris passed over the spillways of those structures during the peak inflow periods, so that the total volume eroded from the individual watersheds are in excess of the figures given.

Estimated Volume of Debris in Basin Prior to Feb. 29: Volumes given in this column are based upon estimated observed quantities deposited in the various debris basins up to February 27. In some cases the basins had been recently cleaned out, and in other cases relatively little deposition had occurred since their construction.

The last three columns are self-explanatory.

Los Angeles County Flood Control District

ESTIMATED AMOUNTS OF DEBRIS DEPOSITED IN DEBRIS BASINS FROM FEBRUARY 28 - MARCH 3, 1938

March 15, 1938

Debris basin	Max. debris Capacity	Est. Vol. debris in basins Mar. 3: Cu. yds.	Est. Vol. debris in basins prior to Feb. 28 - cu. yds.	Est. Vol. debris deposited in basin during storm - Feb. 28 to Mar. 3 cu. yds.	Area water-shed sq. mi.	Deposition in cu. yds. per sq. mi.
Hained	Unknown	35,000	none	35,000	1.53	23,000
Dunsmuir	128,200	125,000	20,000	105,000	.84	125,000
Shields	45,500	33,500 ^{1/2}	1,000	32,500	.27	120,000
Eagle-Goss	71,900	36,000	1,000	35,000	.61	57,000
Pickens	112,800	122,000 ^{1/2}	12,000	110,000	1.84	60,000
Hall-Beekley	89,300	97,000 ^{1/2}	10,000	87,000	.84	103,000
Snover	34,800	28,000	1,000	27,000	.23	117,000
Hay	37,800	19,000	1,000	18,000	.20	90,000
Verdugo	105,700	106,000	15,000	91,000	15.24	----
Lincoln	23,500	18,000	1,000	17,000	.50	34,000
Fern	16,600	15,000	500	14,500	.30	48,000
West Ravine	28,400	21,000	500	20,500	.25	82,000
Fair Oaks	14,300	13,000	500	12,500	.21	60,000
Las Flores	34,000	34,400 ^{1/2}	1,000	33,400	.42	80,000
Brand	69,500	15,000	2,000	13,000	1.03	13,000
Nichols	32,200	21,000	3,000	18,000	.94	19,000
Total		738,900	69,500	669,400		

^{1/2} Based on Survey Data

Channel Changes

Eight cross-sections at bridges crossing the lower Santa Ana River have been surveyed since the flood. The uppermost bridge, known as Yerba Bridge, is near the lower end of Santa Ana Canyon, cut through the Santa Ana Mountains. The lowest section is at the crossing of the Coast Highway near the ocean. The total length of river included in this stretch, measured along the center of the channel is 107,900 feet (approximately $20\frac{1}{2}$ miles). Computations based on these sections show that there was a net removal of approximately 5,036,000 cubic yards of material in this stretch. All sections show considerably more scour than deposition.

Channel Changes

High cross-sections at bridges crossing the lower Santa Ana River have been surveyed since the flood. The upstream bridge, known as Yerba Buena bridge, is near the lower end of Santa Ana Canyon, and through the Santa Ana Mountains. The lowest section is at the crossing of the Coast Highway near the ocean. The total length of river included in this stretch, measured along the center of the channel is 107,700 feet (approximately 20 1/2 miles). Computations based on these sections show that there was a net removal of approximately 5,050,000 cubic yards of material in this stretch. All sections show considerably more silt than deposition.

FOOTNOTES TO ACCOMPANY SUMMARY OF DATA
COLLECTED FOR SECTIONS 3 a AND 3 b (EROSION)

1. Cucamonga - debris basins in 10.3 sq. miles area.
2. All debris markers established by Orange County Flood Control Districts, completely washed away. No estimates of sedimentation available.
3. Big Tujunga - $4\frac{1}{2}$ miles road washed out.
4. Soledad Canyon - 3 miles road washed out.
5. Bouquet Canyon - 20 miles road affected.
6. Elizabeth Lake Road - 20 miles of road affected.
7. San Bernardino County - 12,600 lin. ft. of channels 40' wide and 8' deep plus 5 miles of Santa Ana River and 3 miles Mill Creek.
8. 2 to 4 inches in settling ponds.
9. Serious damage is reported to agricultural areas from the infection of soil, roots and trunks of trees, by fungus infected debris deposition.
10. One farmer reported a cost of 15 cents per tree for removal of silt averaging 1 foot in depth, for a few feet around his trees, with 30 cents per hour labor.
11. San Bernardino - agricultural loss. Brown rot and water rot showing up in west portion of county as result of deposition.
12. Value of land loss \$200 per acre. 2 to 6 feet in depth.
13. 25 acres, 2 inches to three feet of deposition.
14. Stump-holes filled and debris on property.
15. \$4,000,000 is estimated as the total damage to State Highways in the flood area. Approximately \$1,000,000 is assigned to bridges. No estimate is available for the amount of deposition or monetary value of deposition damage. Slides were reported as the largest item to be considered in debris removal.

FOOTNOTES TO ACCOMPANY SUMMARY OF DATA
COLLECTED FOR SECTIONS 1 AND 2 (KNOX) 1938

1. Census - debris basins in 10.5 sq. miles area.
2. All debris basins established by Orange County Flood Control District, completely washed away. No estimates of sedimentation available.
3. Big Turkey - 1.5 miles road washed out.
4. Salado Canyon - 5 miles road washed out.
5. Bunker Canyon - 20 miles road affected.
6. Alamo Canyon - 20 miles of road affected.
7. San Bernardino County - 12,000 lbs. of debris 10' wide and 8' deep plus 5 miles of debris and 5 miles of debris.
8. 2 to 4 inches in settling ponds.
9. Debris damage is reported to agricultural areas from the location of soil, roots and trunks of trees, by debris deposited.
10. One farmer reported a loss of 12 cents per acre for removal of debris averaging 1 foot in depth, for a few feet around his trees, with 30 cents per hour labor.
11. San Bernardino - agricultural loss. Brown rot and water rot showing up in west portion of county as result of deposition.
12. Value of land loss \$200 per acre. 2 to 6 feet in depth.
13. 25 acres, 2 inches to three feet of deposition.
14. Swamp-holes filled and debris on property.
15. \$1,000,000 is estimated as the total damage to State Highways in the flood area. Approximately \$1,000,000 is estimated to bridge. No estimate is available for the amount of deposition or monetary value of deposition damage. Barges were reported as the largest item to be considered in debris removal.

16. 75 miles. 2 inches to three feet of deposition.
17. 1200 miles of county road included.
18. 8 miles of road lost in San Antonio Canyon.
19. 20,000 cu. yds. estimated as deposited in Santa Monica Canyon.
20. 100 miles. 2 inches to three feet of deposition.
21. 2 miles. One to four feet of deposition. 10 miles, two to six inches in deposition.
22. Pomona - deposit reported on street. 1500 ft. long, 30 ft. wide, average depth 15 inches.
23. Mesmer City - reported as having greatest concentration of silt deposition in county. $2\frac{1}{2}$ sq. miles with average depth of 1 ft. deposit on private property $2\frac{1}{2}$ ft. on streets.
24. Sunset Boulevard in West Hollywood reported silted in up to 6 ft. depth for 2000 yards.
25. Colton - Storm channel within city limits - 2 miles long, 60 ft. wide, silted $\frac{1}{4}$ feet deep. Two square miles in city limits. Average deposit 2 ft. deep, varies up to 5 feet depth.
26. Upland - 1000 cu. yds. excavation every storm for the last 3 years, only, since fire in watershed above.

16. 75 miles. 2 inches to three feet of deposition.
17. 1200 miles of country road included.
18. 2 miles of road loss in San Antonio Canyon.
19. 20,000 cu. yds. estimated as deposited in Santa Monica Canyon.
20. 100 miles. 2 inches to three feet of deposition.
21. 2 miles. One to four feet of deposition. 10 miles, two to six inches in deposition.
22. Roman - deposits reported on street. 1500 ft. long, 30 ft. wide, average depth 15 inches.
23. Roman City - reported as having greatest concentration of silt deposition in country. 25 sq. miles with average depth of 1 ft. deposit on private property 2 1/2 ft. on streets.
24. Sunset Boulevard in West Hollywood reported silted in up to 6 ft. depth for 2000 yards.
25. Colton - 6000 channels within city limits - 2 miles long, 60 ft. wide, silted 1 foot deep. Two square miles in city limits. Average deposit 2 ft. deep, varies up to 5 foot depth.
26. Upland - 1000 cu. yds. excavation every storm for the last 5 years. only, since five in watershed above.
27. San Bernardino - excavation every storm for the last 5 years. silted up to four feet in some places.
28. San Gabriel - excavation every storm for the last 5 years. silted up to four feet in some places.
29. San Luis - excavation every storm for the last 5 years. silted up to four feet in some places.
30. San Jose - excavation every storm for the last 5 years. silted up to four feet in some places.
31. San Juan - excavation every storm for the last 5 years. silted up to four feet in some places.
32. San Marcos - excavation every storm for the last 5 years. silted up to four feet in some places.
33. San Mateo - excavation every storm for the last 5 years. silted up to four feet in some places.
34. San Pedro - excavation every storm for the last 5 years. silted up to four feet in some places.
35. San Ramon - excavation every storm for the last 5 years. silted up to four feet in some places.
36. San Rafael - excavation every storm for the last 5 years. silted up to four feet in some places.
37. San Ramon - excavation every storm for the last 5 years. silted up to four feet in some places.
38. San Rafael - excavation every storm for the last 5 years. silted up to four feet in some places.
39. San Ramon - excavation every storm for the last 5 years. silted up to four feet in some places.
40. San Rafael - excavation every storm for the last 5 years. silted up to four feet in some places.

APPENDIX II

SECTION 3 c.

STORM OF FEBRUARY 26 - MARCH 3, 1938

REPORT ON FLOOD DAMAGE SURVEY TRIP IN SAN GABRIEL,
LITTLE DALTON, BIG DALTON AND SAN DIMAS, SAN ANTONIO WATERSHEDS

March 18, 1938

By

William T. Corum
Assistant Civil Engineer
U. S. Forest Service

REPORT OF FERRYMAN ON FLOOD DAMAGE SURVEY TRIP IN SAN GABRIEL

LITTLE DARTON, HIS DARTON AND SAN DIBBS, SAN ANTONIO WATERWORKS

MARCH 10, 1935

APPENDIX II - SECTION 3c.

REPORT ON FLOOD DAMAGE

SURVEY TRIP

March 18, 1938

In compliance with instructions from Chas. J. Kraebel, Senior Silviculturist, to inspect damage and causes of damage to some of the important drainages in and adjacent to the Angeles Forest. A reconnaissance trip was made by the writer in the company of Mr. W. L. Minaker, Associate Civil Engineer.

The trip was made in Government car from Glendora, over the Little Dalton road to Camp Bonita on the San Gabriel River and to Camp Baldy in the San Antonio Canyon.

Much evidence of excessive precipitation was found in enormous road slides and in occasional surface erosion and gullies in places where cover was nonexistent or in poor condition.

The main stream channels in all cases were canyon-wide from hillside to hillside. Small tributary drains were characteristically severely cut while forest litter and cover remained intact to the edge of cutting. Roads apparently contributed considerable amount to the load of the flood but it is not felt that this contributed much to the total amount of material moved from the stream channels. Slides on slopes not cut by roads were not uncommon. One area between the East Fork and Dry Canyon did have quite a number of slides but very few reached water courses.

APPENDIX II - SECTION 3c

REPORT ON FLOOD DAMAGE

BUENY TRIP

March 18, 1938

In accordance with instructions from Chief J. Knebel, Senior Silviculturist, to inspect damage and cause of damage to some of the important fireplaces in and adjacent to the Angeles Forest. A reconnaissance trip was made by the writer in the company of Mr. W. L. Miner, Associate Civil Engineer.

The trip was made in Government car from Glendale, over the Little Belton road to Camp Belton on the San Gabriel River and to Camp Belton in the San Antonio Canyon.

When evidence of extensive precipitation was found in enormous road slides and in occasional surface erosion and gullies in places where cover was nonexistent or in poor condition.

The main stream channels in all cases were canyon-wide from hillside to hillside. Small tributary ditches were characteristically severely cut while forest litter and cover remained intact to the edge of cutting. Roads apparently contributed considerable amount to the load of the flood but it is not felt that this contributed much to the total amount of material moved from the stream channels. Slides on slopes not cut by roads were not uncommon. One area between the East Fork and Dry Canyon did have quite a number of slides but very few reached water courses.

It was interesting to note that most stream courses started out scouring the stream channel according to the flow which became greater as it moved along but the East Fork apparently started out with a large volume right at its source against the side of Mt. San Antonio. This phenomenon is clearly shown in photographs of the area attached to and made a part of this report.

Nearly all developments outside of the dam in San Gabriel Canyon bottoms were destroyed.

Camp Baldy in the San Antonio Canyon was severely damaged with more than half of the development in this area wiped out. Bear Creek tributary damaged much of the area near the entrance to Camp Baldy just downstream from the Guard Station. The San Antonio road down the canyon was completely washed out about a mile below Camp Baldy.

The same general watershed conditions of the San Gabriel appear to apply to the other watersheds observed; Little Dalton, Big Dalton, and San Antonio. Photographs of Lytle Creek and Cajon Pass also indicate the same general conditions.

WILLIAM T. CORUM

Assistant Civil Engineer

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The area general watershed conditions of the San Gabriel appear to apply to the other watersheds observed; Little Dalton, Big Dalton, and San Antonio. Photographs of Little Creek and Canyon Pass also indicate the same general conditions.

WILLIAM T. BOGUM

Assistant Civil Engineer

APPENDIX II

Section 3d

Storm of February 26 - March 3, 1938.

WATERSHED EROSION, FOREST VEGETATION, AND BURNED AREAS

By

Clark H. Gleason
Assistant Forester
California Forest and Range Experiment Station

It was determined that the fire was started

APPENDIX II

Section 34

Storm of February 20 - March 2, 1938

The storm of February 20 - March 2, 1938, was a severe one, with heavy rain and strong winds. The rain fell in heavy showers, and the winds were strong and gusty. The storm caused considerable damage to the forest, and the ground was very muddy.

WATERSHED EROSION, FOREST VEGETATION, AND BURNED AREAS

The storm caused considerable damage to the forest, and the ground was very muddy. The rain fell in heavy showers, and the winds were strong and gusty. The storm caused considerable damage to the forest, and the ground was very muddy.

BY

Clark H. Glasgow
Assistant Forester
California Forest and Range Experiment Station

WATERSHED EROSION, FOREST VEGETATION, AND BURNED AREAS

The great storm of early March 1938 approached the magnitude of those responsible for building the tremendous alluvial fans that characteristically foot the mountains of southern California. Some mountain canyons were scoured clean of debris accumulated during many years of lesser and recently deficient rainfall, great volumes of it were moved out into the inter-montane valleys, and large quantities remain on many canyon bottoms.

Plate 18 shows the typical denudation of large canyon bottoms. Rainfall intensity and duration were ~~unsufficient~~ insufficient to cause widespread slipping of soil masses from both disturbed and natural mountain sides, as shown in Plate 5. Except in special local areas, this slumping was most serious on south exposures. Debris from this source was appreciable in a few places, but channel scouring delivered by far the greatest volumes. These slumps were conditioned by hidden causes not yet classified. It was noticeable that gradients in excess of 70 percent were most frequently affected.

Widespread shoestring gullying occurred in areas denuded by fire, and in regions of naturally sparser vegetative cover such as the sagebrush type that grows under near-desert conditions in the upper Santa Ana watershed. Such gullies were not developed under the heavy litter blanket generated by normal chaparral and other good vegetative cover.

The recognized effect of burned and otherwise denuded areas in accelerating erosion was operative, although masked by the delivery of unprecedented water and debris volumes, even by well-forested and undisturbed canyons. A few clear-cut cases have been isolated that show this restraining influence of vegetative cover.

The great storm of early March 1938 approached the region of these responsible for building the tremendous alluvial fans that characterize the mountain of southern California. Some mountains were covered with debris accumulated during many years of lesser and recently different rainfall. Great volumes of it were moved out into the inter-mountain valleys, and large quantities remain on many canyon bottoms.

Plate 18 shows the typical denudation of large canyon bottoms. Rainfall intensity and duration were sufficient to cause widespread slipping of soil masses from both disturbed and undisturbed mountain sides, as shown in Plate 5. Except in special local areas, this slumping was most serious on south exposures. Debris from this source was appreciable in a few places, but channel scouring delivered by far the greatest volumes. These slumps were conditioned by hidden causes not yet classified. It was noticeable that gradients in excess of 70 percent were most frequently affected.

Widespread slumping following rainfall occurred in areas denuded by fire, and in regions of naturally sparser vegetative cover such as the sagebrush type that grows under near-desert conditions in the upper Santa Ana watershed. Such gullies were not developed under the heavy litter blanket generated by natural chaparral and other good vegetative cover. The recognized effect of burned and otherwise denuded areas in accelerating erosion was operative, although masked by the delivery of well-forested and undisturbed waters and debris volumes, even by well-forested and undisturbed areas. A few clear-cut cases have been isolated that show this restraining influence of vegetative cover.

Examination of areas burned in the last 5 years revealed varying degrees of erosion in this storm. Amount of increase with recency of burn is difficult to evaluate without further careful study. Although apparently more numerous in the Brown Mountain and Las Flores burns of 1934 and 1935 (Plate 5), land slips are regarded as more a function of gradient, than slope denudation. Further study of this phenomenon is greatly to be desired.

Significant erosion occurred in the Bouquet burn of 1937. Retained by highway fills and partly as a delta in Bouquet Reservoir, the deposits will be measured for estimate of the erosion rate. The Los Angeles Bureau of Water and Power is furnishing a field crew to make these measurements, and has already completed a topographic map of the basins before runoff occurred, to serve as an accurate basis of estimate.

Significant debris volumes were again yielded by Frankish Canyon, which was denuded by fire in 1935 and immediately sown to mustard cover crop (Plates 1 and 3). Examination showed (1) some new gullies, (2) litter and growing vegetation which had been materially increased by the sown mustard, and (3) scouring of the wash at and below the canyon mouth. It is believed that a significant proportion of the debris moved by this wash was derived from channel gouging on the outwash fan, but a more careful study should be made to determine this. This mouth of Harwood Canyon, which heads in the same burned area, also shows channel cutting, indicating a less heavily loaded stream than has been the case at that point in previous years since the fire. ^{1/}

^{1/} Meadowcroft and Gleason. Upland Flood Damage Appraisal. July 24, 1936, file E, Supervision, San Bernardino, Upland Floods. (Confidential report on damage the first winter following fire, for Regional Engineer and Director of Experiment Station, Region 5.)

damage the first winter following fire, for Regional Engineer and Director
Life E. Supervision, San Bernardino, United States. (Confidential report on
Nashawatt and Gibson. United Flood Damage Appraisal, July 2, 1956.

the fire.

located stream than has been the case at that point in previous years since
same burned area, also shows channel cutting, indicating a less heavily
be made to determine this. This mouth of Barwood Canyon, which he is in the
from channel cutting on the opposite side, but a more careful study should
that a significant proportion of the debris moved by this wash was derived
and (3) scouring of the wash at and below the canyon mouth. It is believed
growing vegetation which had been materially increased by the same wash,
crop (Plates I and 2). Examination showed (1) some new gullies, (2) litter and
which was denuded by fire in 1955 and immediately soon to mustard cover
Significant debris volumes were again yielded by Fremont Canyon.

occurred, to serve as an accurate basis of estimate.

and has already completed a topographic map of the basin before runoff
of water and power is furnishing a field crew to make these measurements,
will be measured for estimate of the erosion rate. The Los Angeles Bureau
by highway fills and partly as a delta in Bourns Reservoir, the deposits
Significant erosion occurred in the longest part of 1955. Retained

desired.

than slope denudation. Further study of this phenomenon is greatly to be
1955 (Plate 2), land slips are regarded as more a function of gradient,
is more known in the Brown Mountain and Las Flores burn of 1954 and
is difficult to evaluate without further careful study. Although apparent-
degrees of erosion in this basin. Amount of increase with tendency of burn
Examination of areas burned in the last 5 years revealed varying

Paired 1/50-acre ~~Sanoff~~ plots in areas burned 2 to 5 years ago yielded striking evidence of the effectiveness of vegetative cover in controlling erosion. Typical of these are the Haines Canyon plots shown in Plate 4, which were installed in the Pickens burn of 1933. Completed after the heavy 1933-34 New Year's storm, this installation caught debris at a direct conversion rate of approximately 19,000 cu. yds. per sq. mi., eroded during the 3-inch storm of February 1934. In the current 1938 storm, when 5 times that amount of rain fell with much heavier sustained intensity, no erosion occurred; the identical plot area was completely stabilized by the present cover of vegetation.

Erosion rates measured by some of the debris basins in the region (Plate 7) are given in table 1, whose figures show the instability of burned areas as compared with those in a more normal condition. Unfortunately, it is almost impossible to find for comparison drainages that have not suffered within historic times severe damage by fire or other disturbance.

Paired watersheds roughly estimated to contain 2 acres each were located at Eagle Rock, one of which had been burned last fall. Effect of this denudation was apparent even to local property owners, who were much concerned over the greater volumes of water and debris that have been issuing from the burned drainage this winter. Canyon-mouth silt deposits quickly measured by the writer, gave this comparison:

Canyon No.	Approximate area Acres	Condition	Debris in place (cu. ft.)	Remarks
A	2	Unburned	400	Total catch of debris for winter. Small portion of drainage burned.
B	2	Burned	4000	Partial catch of debris Feb. 26 - Mar. 19 storms only.

Placed 170-acre small plots in areas burned 2 to 5 years ago
 included existing evidence of the effectiveness of vegetative cover in con-
 trolling erosion. Typical of these are the Haines Canyon plots shown in
 Plate 1, which were installed in the Haines burn of 1935. Completed after
 the heavy 1935-36 New Year's storm, this installation caught debris at a
 direct conversion rate of approximately 12,000 cu. yds. per sq. mi., eroded
 during the 3-inch storm of February 1936. In the current 1936 storm, when
 5 times that amount of rain fell with much heavier sustained intensity, no
 erosion occurred; the identical plot area was completely stabilized by the
 present cover of vegetation.

Erosion rates measured by some of the debris basins in the region
 (Plate 7) are given in Table 1, whose figures show the inability of burned
 areas as compared with those in a more normal condition. Unfortunately, it
 is almost impossible to find for comparison drainage basins that have not suffered
 within historic times severe damage by fire or other disturbance.
 Placed waterbombs roughly estimated to contain 2 acres each were
 located at Eagle Rock, one of which had been burned last fall. Effect of
 this disturbance was apparent even to local property owners, who were much
 concerned over the greater volume of water and debris that have been seen
 run from the burned drainage this winter. Canyon-mouth alluvial deposits
 quickly measured by the writer, gave this comparison:

No.	Area	Canyon : Approximate :		Remarks
		Condition :	Debris in :	
		area	place (cu. ft.)	
A	2	Unburned	1400	Total catch of debris for winter, small portion of drainage burned.
B	2	Burned	14000	Partial catch of debris Feb. 26 - Mar. 19 storm only.

Table 1. - Erosion deposits in Los Angeles County Flood Control
District debris basins. Storm of February 26 -
March 3, 1938.

(Tentative figures, subject to correction)

	Watershed area sq. mi.	Debris this storm (Cu. yds. / sq. mi.)	Remarks
Nichols	.94	19,000	Watershed unburned, but seriously scarred with real estate development roads.

Pickens Burn of 1933

Haines	1.53	23,000	Watershed 3/5 burned
Dunsmuir	.84	125,000	Totally burned
Shields	.27	163,000	Totally burned
Eagle-Goss	.61	57,000	Tot ally burned
Pickens	1.84	59,000	Totally burned
Hall-Beckley	.84	113,000	Totally burned
Snover	.23	117,000	Totally burned

Las Flores Burn of 1935

Lincoln	.50	34,000	Totally burned
Fern	.30	18,000	Totally burned
West Ravine	.25	82,000	Totally burned
Fair Oaks	.21	60,000	Totally burned
Las Flores.	.42	79,000	Totally burned

Table 1. - Erosion Accidents in Los Angeles County Flood Control District during 1935.
 Period: 1935.

(Tentative figures, subject to correction)

Location	Area, sq. mi.	Area, cu. yds. (approx.)	Remarks
Nichols	1.25	12,000	Watered and buried, but seriously covered with soil, estate development roads.

Persons Buried in 1935

Haines	1.25	12,000	Watered and buried 2/5 buried
Thompson	1.25	12,000	Totally buried
Whitman	1.25	12,000	Totally buried
Wright-Goss	1.25	12,000	Totally buried
Wright	1.25	12,000	Totally buried
Wright-Bosley	1.25	12,000	Totally buried
Wright	1.25	12,000	Totally buried

Los Angeles Area of 1935

Lincoln	1.25	12,000	Totally buried
Wright	1.25	12,000	Totally buried
Wright	1.25	12,000	Totally buried
Wright	1.25	12,000	Totally buried
Wright	1.25	12,000	Totally buried

Erosion of roads and damage from erosion caused by roads was severe in the whole region, and contributed significant quantities of debris. It may be remarked here that roads constitute another case of watershed denudation that is especially serious because of the profound soil disturbance and typical concentration of surface runoff into erosion foci.

Summary

With the occurrence of flood damage such as characterized this storm, the question is bound to arise as to the actual value of vegetation in restraining erosion in storms of this size. At first glance it may appear that plants exerted no effect, since damage is so apparent and widespread. In consideration of the field examination, however, there can be no question that vegetation did exert a tremendous measure of control, and that without it -- had the watersheds been largely denuded by fire last summer or within the last few years -- the volume of debris delivered must have been many times greater than it was.

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APPENDIX II

Section 3 e

RECONNAISSANCE OF ROAD DAMAGE
IN MOUNTAIN WATERSHEDS OF SOUTHERN CALIFORNIA
STORM OF MARCH 1938

By

D. M. Ilch
Assistant Silviculturist
California Forest and Range Experiment Station
U. S. Forest Service

APPENDIX II

Section 5

RECOMMENDATIONS OF ROAD DAMAGE

IN MOUNTAIN WATERSHEDS OF SOUTHERN CALIFORNIA

STORM OF MARCH 1935

By

D. M. Litch

Assistant Silviculturist

California Forest and Range Experiment Station

U. S. Forest Service

March 21, 1938

RECONNAISSANCE OF ROAD DAMAGE
IN MOUNTAIN WATERSHEDS OF SOUTHERN CALIFORNIA

Storm of March 1938

In accordance with instructions from the Director and Mr. Kraebel, a quick reconnaissance was made of representative roads in the mountain watersheds of southern California during the week of March 14 to 19, to determine the kind and amount of damage done by the storm of February 26 to March 3, 1938.

The volumes of soil displaced or deposited during the storm were taken as the chief index of damage. Since it was impossible to examine all roads, the examination was made on a number of selected roads as a basis for estimating the losses from similar roads in watersheds having the same general characteristics of slope, soil, cover and rainfall.

All roads were grouped into three broad classes as follows:

Class A - high standard, paved, high-gear mountain roads of heavy through-cut and fill construction.

Class B - high standard development roads of side-hill bench or end-haul type of construction.

Class C - medium and low standard development road of minimum width constructed with tractor or trailbuilder.

This last type of road includes truck trails, motorways, county or private roads included in the forest protection system. Although truck trails are of two types, high and low standard, no segregation was attempted because of the difficulty of distinguishing between the two classes. During

March 21, 1938

RECONSTRUCTION OF ROAD DAMAGE
IN MOUNTAIN WATERSHEDS OF SOUTHERN CALIFORNIA

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Class C - medium and low standard development road of minimum width constructed with tractor or trailblader.

This last type of road includes truck trails, motorways, county or

private roads included in the forest protection system. Although truck

trails are of two types, high and low standard, no segregation was attempted because of the difficulty of distinguishing between the two classes. During

construction both standards have been so frequently modified to meet local conditions that most roads of this type are really a combination of the two standards.

On the high standard paved mountain highways such as the Angeles Crest, Waterman Canyon and San Gabriel highways, the heaviest losses occurred as slides from cut banks, side canyon deposition, fill slumps and washouts resulting from side canyon drainage and debris.

Cut bank slides were heaviest on sections of the Angeles Crest and San Gabriel highways where preparation for excavation was made by deep blasting. Cuts made by power rippers, shovels and hand labor show a minimum of slide material, usually in the form of small talus slopes, soil or decomposed rock pockets released from sloping rock ledges. In a few places in these latter cuts the peculiar nature of the rock, a deeply weathered feldspar subject to thorough saturation produced large slumps.

Heavy losses in fill and roadbed material emphasized the inadequacy of drainage facilities. This is particularly true of through-fill construction where debris from side canyons plugged the culverts on the up-canyon sides of the fills. The fills thus acted as dams and the impounded water produced pressure seepage through the fill soil, causing large fill slumps or complete washouts of the road.

On the high standard highways, bare fill slopes, not exposed to drainage water, still showed excessive gully and sheet erosion from runoff of the rainfall.

Concentrated road surface runoff on fill slopes greatly increased the volume of erosion.

Undercutting of roadbed and fill slopes by streams in the lower

construction both standards have been as frequently modified to meet local conditions that most roads of this type are really a combination of the two standards.

On the high standard paved mountain highways such as the Angeles Crest, Western Canyon and San Gabriel highways, the heaviest losses occurred as slides from cut banks, slide canyon deposition, fill slumps and washouts resulting from slide canyon drainage and debris. Cut bank slides were heaviest on sections of the Angeles Crest and San Gabriel highways where preparation for excavation was made by deep blasting. Cuts made by power ripers, shovels and hand labor show a minimum of slide material, usually in the form of small talus slopes, soil or decomposed rock pockets released from sloping rock ledges. In a few places in these latter cuts the peculiar nature of the rock, rapidly weathered foliages subject to thorough saturation produced large slumps. Heavy losses in fill and roadbed material emphasized the inadequacy of drainage facilities. This is particularly true of through-fill construction where debris from slide canyons rimmed the surface on the up-canyon sides of the fills. The fills thus acted as dams and the impounded water produced pressure escape through the fill soil, causing large fill slumps or complete washouts of the road.

On the high standard highways, bare fill slopes, not exposed to drainage water, still showed excessive gully and sheet erosion from runoff of the rainfall. Concentrated road surface runoff on fill slopes greatly increased the volume of erosion.

Undercutting of roadbed and fill slopes by streams in the lower

portions of the canyons was a major factor in destroying sections of all classes of roads. In a few places retaining walls at the toes of such slopes prevented this type of damage.

Both Class B. and C. roads were heavily damaged by side canyon wash-outs and slides from steep cut banks. Fill or overcast slope erosion was less serious on B and C type roads. Inadequate drainage was the most potent contributing factor on all roads.

Fill slopes treated by some erosion control method were on the whole satisfactory. The brush wattle and hay or litter cover method proved very satisfactory and provided almost complete protection to fill slopes from slope runoff. Some methods were inadequate and failed completely but analysis has not been made at this writing. Certain failures were observed, as the result of through-fill seepage causing slumps, but not from failure of well established vegetation on slopes where the treatment was well done.

D. M. ILCH
Assistant Silviculturist

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D. M. LICH
Assistant Silviculturist

ESTIMATED VOLUME OF ROAD DAMAGE FROM SLIDES, FILL SLOPE EROSION AND OTHER CAUSES ON SAMPLE ROADS
AFTER THE STORM OF MARCH 1938

Volume of Material in Cubic Yards
Per mile of Road Based on Reconnaissance of Nine Roads

	: Angeles	: San Gabriel	: Waterman	: Glendora	: City Crk.	: City Crk.	: Monroe	: Cucamonga	: Ridge Route
	: Crest	: Highway	: Canyon	: Mt. Road	: Road	: T. T.	: T. T.	: T. T.	: (Santa Clara)
1. Slides. earth	:	:	: 5	: 190	:	:	: 195	:	:
	: 65,000	: 267,100	:	:	: 60	: 20	:	: 20	:
2. Slides. rock	:	:	: 620	: 2,855	:	:	: 25	:	: 350
3. Slump, fill	:	: 2,500	:	:	:	:	:	:	:
Slope	: 8,025	:	:	: 630	:	:	: 65	: 5	: 100
4. Erosion,	:	:	:	:	:	:	:	:	:
road surface	:	:	:	: 20	: 20	: 3	: 5	: 10	:
5. Erosion, fill	:	:	:	:	:	:	:	:	:
slope untreated	: 45,000	: 10	: 610	: 25	: 250	: 175	: 370	: 2	: 200
6. Erosion, surface	:	:	:	:	:	:	:	:	:
slope treated	:	:	: 50	: 5	:	:	:	:	:
7. Erosion, surface	:	:	:	:	:	:	:	:	:
drainage outfall	: 3,400	: 675	: 115	: 200	: 1600	: 200	: 870	: 105	: 150
8. Stream undercut	: 6,000	: 6,000	:	: 10	: 300	:	: 100	:	: 50
9. Washout, side	:	:	:	:	:	:	:	:	:
canyon	:	:	: 30,000	:	:	: 150	: 50	:	:
10. Deposition, side	:	:	:	:	:	:	:	:	:
canyon	: 20,750	:	: 20,000	: 3	: 85	:	: 10	: 20	: 150
TOTAL	: 148,175	: 276,285	: 51,400	: 3,938	: 2,315	: 548	: 1,690	: 162	: 1,000

other office at Istanbul to conduct
business in capital
should wish to communicate with head office to other

NOTE: The values shown hereon are for the most part rough estimates, obtained from public and private agencies where such data was available; totals apply only for the items shown and do not represent totals for the entire flood area.

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
CALIFORNIA-NEVADA - REGION 10 HARRY E. REDDICK, REGIONAL CONSERVATOR

Data collected prior to March 19, 1938 - by -
Louis W. Waters- for Ventura County
Carl V. Gragg - Orange and Riverside Counties
Donald C. Johnson -Los Angeles and San Bernardino Counties

SUMMARY OF DATA COLLECTED FOR ITEM 3 (EROSION), SUB-ITEMS (a) AND (b), SPECIAL REPORT ON FLOOD OF MARCH 2, 1938, - SOUTHERN CALIFORNIA

DESCRIPTION (Note: See Attached Sheets for Footnotes indicated.)	LOS ANGELES COUNTY			ORANGE COUNTY			RIVERSIDE COUNTY			SAN BERNARDINO COUNTY			VENTURA COUNTY			TOTALS FOR ALL COUNTIES		
	Deposition Cu. Yds.	Damages Cost of Removal, etc.	Bank Removal Cu. Yds.	Deposition Cu. Yds.	Damages Cost of Removal, etc.	Bank Removal Cu. Yds.	Deposition Cu. Yds.	Damages Cost of Removal, etc.	Bank Removal Cu. Yds.	Deposition Cu. Yds.	Damages Cost of Removal, etc.	Bank Removal Cu. Yds.	Deposition Cu. Yds.	Damages Cost of Removal, etc.	Bank Removal Cu. Yds.	Deposition Cu. Yds.	Damages Cost of Removal, etc.	Bank Removal Cu. Yds.
SUB-ITEM (a): Storage Reservoirs: Pine Canyon Dam and Reservoir	4840,000	\$ 577,600																
Pasadena Water Supply Reservoir	400																	
Devil's Gate Dam	1935,000	120,000																
Puddingston Diversion Dam	84,045																	
Santa Anita Dam	589,690	416,720																
Sawpit Dam	176,623	146,527																
Sierra Madre Dam	68,000	52,536																
Sunset Canyon Dam	9,000	8,535																
Total	7702,758	\$ 1213,918														7,702,758	\$ 1,213,918	
Debris Basins: Los Angeles County Flood Control Debris Basins	685,500	632,000																
Cucamonga Debris Works (1)										200,000	\$ 40,000							
Total	685,500	\$ 632,000								200,000	\$ 40,000					885,500	\$ 672,000	
Channels: Orange County Storm Drains Excluding Santa Ana River (2)				15,000	\$ 10,000													
Storm Drains Riverside County							112,000	\$ 85,000										
Corona Storm Drain													500,000	\$ 300,000				
Ventura County Storm Channels																		
Minor Storm Channels in Los Angeles City	25,000	\$ 18,000																
Arroyo Seco Channel	444,000	100,000																
Eaton Wash			10,000															
Tuna Canyon			8,000															
Dalton Canyon			10,000															
Little Tujunga Canyon Road			45,000															
Big Tujunga (3)			200,000															
Soledad Canyon (4)			125,000															
Boquet Canyon (5)			50,000															
Elizabeth Lake Road (6)			100,000															
Santa Monica Canyon	20,000	10,000																
San Bernardino County (7)										2041,185	484,000							
San Bernardino City										1441,185	432,400							
Total	489,000	\$ 128,000	548,000	15,000	\$ 10,000		112,000	\$ 85,000		3482,370	\$ 916,400		500,000	\$ 300,000		4,598,370	\$ 1,439,400	548,000
Spreading Grounds: Santa Clara Valley Spreading Grounds													750	550				
Total													750	\$ 550		750	\$ 550	

NOTE: The values shown hereon are for the most part rough estimates, obtained from public and private agencies where such data was available; totals apply only for the items shown and do not represent totals for the entire flood area.

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
CALIFORNIA-NEVADA - REGION 10 HARRY E. REDDICK, REGIONAL CONSERVATOR

SUMMARY OF DATA COLLECTED FOR ITEM 3 (EROSION), SUB-ITEMS (a) and (b), SPECIAL REPORT ON FLOOD OF MARCH 2, 1938, - SOUTHERN CALIFORNIA

Data collected prior to March 19, 1938 - by -
Louis W. Waters - for Ventura County
Carl V. Gragg - Orange and Riverside Counties
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DESCRIPTION	LOS ANGELES COUNTY			ORANGE COUNTY			RIVERSIDE COUNTY			SAN BERNARDINO COUNTY			VENTURA COUNTY			TOTALS FOR ALL COUNTIES		
	Deposition Cu. Yds.	Damages Cost of Removal, etc.	Bank Removal Cu. Yds.	Deposition Cu. Yds.	Damages Cost of Removal, etc.	Bank Removal Cu. Yds.	Deposition Cu. Yds.	Damages Cost of Removal, etc.	Bank Removal Cu. Yds.	Deposition Cu. Yds.	Damages Cost of Removal, etc.	Bank Removal Cu. Yds.	Deposition Cu. Yds.	Damages Cost of Removal, etc.	Bank Removal Cu. Yds.	Deposition Cu. Yds.	Damages Cost of Removal, etc.	Bank Removal Cu. Yds.
SUB-ITEM (b):																		
Agricultural Areas:																		
Land Planted to Trees and Vines (10	260,000	\$ 90,000								280,000	\$ 100,000		60,000	\$ 50,000	1,000 acres			
San Bernardino Agricultural Area (11																		
Ventura County Agricultural Area (12				4,500,000	\$ 690,000													
Orange County Agricultural Area (							100,000	\$ 25,000										
Riverside County Agricultural Area																		
Total	260,000	\$ 90,000		4,500,000	\$ 690,000		100,000	\$ 25,000		280,000	\$ 100,000		60,000	\$ 50,000	1,000 acres	5,200,000	\$ 955,000	1,000 acres
Urban Areas:																		
Brookside Park, Pasadena		\$ 150,000																
Beach Debris - Long Beach		50,000																
Glendale Urban Area	150,000									1,748,000	\$ 230,000		18,000	\$ 15,000				
San Bernardino													51,300	50,000				
Ventura County, Private Property (13							800,000	\$ 200,000										
Oil Company Property (14				20,000	10,000													
Urban Areas Riverside County				20,000	\$ 10,000		800,000	\$ 200,000		1,748,000	\$ 230,000		69,300	\$ 65,000		2,787,300	\$ 705,000	
Urban Areas Orange County																		
Total	150,000	\$ 200,000											540,000	\$ 235,000				
State Roads: (15													540,000	\$ 235,000		540,000	\$ 235,000	
Ventura County State Roads (16																		
Total																		
County Roads:																		
Orange County Roads				15,000	\$ 13,500													
Riverside County Roads							5,000	\$ 2,500										
Los Angeles (17, (18, (19		\$ 30,000																
Glendora Mt. Road	60,000	30,000																
Ventura County Roads													900,000	\$ 780,000				
Total	60,000	\$ 60,000		15,000	\$ 13,500		5,000	\$ 2,500					900,000	\$ 780,000		980,000	\$ 856,000	
City Streets:																		
Anaheim City Streets				196,000	\$ 100,000													
Fullerton City Streets				10,000	4,500													
Corona City Streets							20,000	\$ 20,000										
City Streets, Ventura County (21													22,000	\$ 20,000				
Pomona (22	3,000	\$ 3,000																
Claremont	50,000	20,000																
Los Angeles (23, (24	800,000	600,000																
Pasadena	40,000	20,000																
Glendale	300,000	120,000																
Burbank	30,000	12,000								120,000*	\$ 100,000*							
Upland and Ontario										1,600	1,100							
Total	1,223,000	\$ 775,000		206,000	\$ 104,500		20,000	\$ 20,000		121,600	\$ 101,100		22,000	\$ 20,000		1,592,600	\$ 1,020,600	

*Colton

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UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
CALIFORNIA-NEVADA - REGION 10 HARRY E. REDDICK, REGIONAL CONSERVATOR

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SUB-ITEM (b): Railroads: San Bernardino County Railroads San Bernardino Railroad Yards Total Public Utilities: San Bernardino Sewage Disposal Works Total GRAND TOTALS										5,500 40,000 45,500	3,000 20,000 \$ 23,000					45,500	\$ 23,000	
										4,000 4,000	4,000 4,000					4,000	\$ 4,000	
																		548,000 Cu. Yds. 1,000 Acre
	10,570,258	\$3,093,918	548,000	4,756,000	\$828,000		1,037,000	\$332,500		5881,470	\$1414,500		2,092,050	\$1,450,550	1,000 acres	24,336,778	\$ 7,124,468	

APPENDIX II

Section 5.

FLOOD DAMAGES

- a. Damage to water spreading systems in southern California - H. F. Blaney
- b. Upper watersheds - C. H. Gleason - See Appendix II, Section 3d and Appendix 1, photographs.
- c. Estimated flood damage to reservoirs, agricultural and urban areas - R. A. Floyd and Phillip Webster

APPENDIX II

Section 5a

MEMORANDUM ON
DAMAGE TO SPREADING SYSTEMS IN
SOUTHERN CALIFORNIA AS RESULT OF
FLOODS CAUSED BY HEAVY RAINS
OF FEBRUARY 28 TO MARCH 4, 1938

By

Harry F. Blaney
Irrigation Engineer
Bureau of Agricultural Engineering

APPENDIX II

Section 2a

MEMORANDUM ON

DAMAGE TO SPRINKLING SYSTEMS IN
SOUTHERN CALIFORNIA AS RESULT OF
FLOODS CAUSED BY HEAVY RAINING
OF FEBRUARY 28 TO MARCH 1, 1935

BY

Harry F. Hines
Irrigation Engineer
Bureau of Agricultural Engineering

MEMORANDUM ON DAMAGE TO SPREADING SYSTEMS IN SOUTHERN CALIFORNIA AS
RESULT OF FLOODS CAUSED BY HEAVY RAINS OF FEBRUARY 28 to MARCH 4, 1938 1/

by Harry F. Blaney, Irrigation Engineer

Division of Irrigation, Bureau of Agricultural Engineering
U. S. Department of Agriculture

The Field Coordinating Committees, eighteen and twenty on Flood Control of U. S. Department of Agriculture met in Los Angeles March 9, and agreed to coordinate their efforts in the collection of data for reports to Bureau chiefs. The Bureau of Agricultural Engineering was assigned the subject of Water Spreading. The statements in this report are tentative and subject to correction.

Spreading Water for Storage Underground

A detailed report on water spreading systems in southern California is given in U. S. Department of Agriculture Technical Bulletin No. 578, recently issued by the Bureau of Agricultural Engineering. The authors, A. T. Mitchelson and Dean C. Muckel, describe water spreading briefly as follows:

"Water spreading is the practice of diverting water from natural channels and spreading it over adjacent porous lands. The operation of a spreading system may be somewhat comparable to an irrigation system, except that instead of attempting to hold the moisture within the root zone of the irrigated crop, rapid percolation to the underground basin is encouraged. The water may be recovered by pumping it back to the surface. One advantage of storing water underground is the reduction of loss by evaporation, because while there is, of course, some evaporation loss during the process of spreading, the spreading usually occurs during that part of the year when evaporation losses are lowest. On the other hand, it may be that not all of the water stored underground is recoverable, but it is believed that the greater portion can be recovered. Any flood flow not stored either naturally or artificially, is obviously wasted.

1/ A large portion of a Memorandum for A. T. Mitchelson on Damage to Spreading Systems prepared by Dean C. Muckel was used in this report.

Los Angeles, California
March 19, 1938

MEMORANDUM ON DAMAGE TO SPREADING SYSTEMS IN SOUTHERN CALIFORNIA AS
RESULT OF FLOOD CAUSED BY HEAVY RAIN OF FEBRUARY 28 TO MARCH 1, 1938

by Harry W. Bimby, Irrigation Engineer

Division of Irrigation, Bureau of Agricultural Engineering
U. S. Department of Agriculture

The Field Coordinating Committee, eighteen and twenty on Flood Control
of U. S. Department of Agriculture met in Los Angeles March 9, and agreed to
coordinate their efforts in the collection of data for reports to Bureau
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Water Spreading. The statements in this report are tentative and subject
to correction.

Spreading Water for Storage Underground

A detailed report on water spreading systems in southern California
is given in U. S. Department of Agriculture Technical Bulletin No. 570,
recently issued by the Bureau of Agricultural Engineering. The authors,
A. T. Nicholson and Dean C. Knebel, describe water spreading briefly

as follows:

"Water spreading is the practice of diverting water from natural
channels and spreading it over adjacent porous lands. The operation of a
spreading system may be somewhat comparable to an irrigation system, except
that instead of attempting to hold the moisture within the root zone of the
irrigated crop, rapid percolation to the underground basin is encouraged.
The water may be recovered by pumping it back to the surface. One advantage
of storing water underground is the reduction of loss by evaporation, because
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ground is recoverable, but it is believed that the greater portion can be re-
covered. Any flood flow not stored either naturally or artificially, is ob-
viously wasted."

A large portion of a memorandum for A. T. Nicholson on damage to
spreading systems prepared by Dean C. Knebel was used in this report.

"Water spreading is to be recommended as practical and economical in certain areas and under certain conditions. The value of this practice is, of course, a local problem depending on the cost of water, type of crops to be irrigated or the use to which the recovered water is to be put. The determination to adopt this method of conservation must be based upon a thorough study of quality and quantity of available flood water for spreading; the surface conditions with reference to slope, soil type, vegetative cover; the possibilities of diversion structures and channels, the underground conditions and numerous other factors.

"The most efficient spreading systems are located on the debris cones of the streams utilized and above the line of intercepting walls. In a description of the formation of these cones it may be well to take as a typical case the debris fans formed by the southern California streams, because these are more pronounced than in other sections where water spreading may be practiced.

"At the mouths of all the canyons descending from the Sierra Madre are cone or fan-shaped accumulations of boulders, cobbles, gravels, and sands over which the streams can pass only at times of flood, because at ordinary stages the flow is completely absorbed in these debris beds. This is particularly true of the smaller streams and especially when the canyons from which the streams debouch are steep.

"Surface flow appears, however, on the larger streams during and even after floods, and in the lower sections there may be found some flowthrough-out the year."

Flood Damage to Spreading Systems

In southern California during the period February 28 to March 4, 1938 heavy rains created flood conditions and caused considerable damage. The greatest loss occurred in Ventura, Los Angeles, San Bernardino, Riverside and Orange Counties. Flood protection works were in many cases inadequate to handle the heavy flow. Streams with storage reservoirs fared better than others although many of the reservoirs were of insufficient capacity to entirely control the run-off.

Little attempt was made to spread water during the flood as the stream flows were beyond the capacity of the spreading diversion works and the normal flood channels intended to carry off excessive run-off. Structures on many of the spreading systems are not designed for the

Water spreading is to be recommended as practical and economical in certain cases and under certain conditions. The value of this practice is, of course, a local problem depending on the cost of water, type of crops to be irrigated or the use to which the recovered water is to be put. The determination to adopt this method of conservation must be based upon a thorough study of quality and quantity of available flood water for spreading; the surface conditions with reference to slope, soil type, vegetative cover; the possibilities of diversion structures and channels; the underground conditions and numerous other factors.

"The most efficient spreading systems are located on the debris cones of the stream bed and above the line of interlocking walls. In a description of the formation of these cones it may be well to take as a typical case the debris fans formed by the southern California streams, because these are more pronounced than in other sections where water spreading may be practiced.

"At the mouth of all the canyons descending from the Sierra Madre are cone or fan-shaped accumulations of boulders, gravels, and sands over which the streams can pass only at times of flood, because at ordinary stages the flow is completely absorbed in these debris beds. This is particularly true of the smaller streams and especially when the canyons from which the streams descend are steep.

"Surface flow appears, however, on the larger streams during the even after floods, and in the lower sections there may be found some flow-through out the year."

Flood Damage to Spreading Systems

In southern California during the period February 28 to March 1, 1935 heavy rains created flood conditions and caused considerable damage. The greatest loss occurred in Ventura, Los Angeles, San Bernardino, Riverside and Orange Counties. Flood protection works were in many cases inadequate to handle the heavy flow. Streams with storage reservoirs fared better than others although many of the reservoirs were at insufficient capacity to entirely control the run-off.

Little attempt was made to spread water during the flood as the stream flows were beyond the capacity of the spreading diversion works and the normal flood channels intended to carry off excessive run-off. Structures on many of the spreading systems are not designed for the

amounts of water they were called upon to control. Enormous quantities of moving sand, Gravel and boulders together with floating debris made diversion of water practically impossible even on those systems where the diversion works were capable of handling the flow.

Even though diversion could have been accomplished the existing spreading systems would not have been sufficient to prevent floods below. For example, on San Antonio Creek a peak flow of 25,000 sec. Ft. was reported and there are only 1100 acres of land set aside for spreading purposes. Using an absorption rate of 1 Sec.-ft. per gross acre or a total of 1100 Sec.-ft. it can be seen that the spreading grounds were entirely inadequate to handle a flood of this size.

As the flow receded, spreading where possible proved to be of value by diminishing the flow across highways and lands in the valleys permitting repair work to start sooner than it could have otherwise.

Damage to spreading areas occurred by the streams breaking out of their normal channel across the debris cones and cutting new channels. During the flood it was noted that a new channel would form on the debris cone and this would then become partially dammed by debris causing the stream to again seek a different channel as it moved down the cone. This meandering of the flood flow resulted in washouts and deposition of debris on portions of the areas set aside for spreading and damaged many of the structures. However, on most of the debris cones there still remains portions of the spreading systems which can be utilized and spreading was started shortly after the flood had passed. Repair work is already under way and every attempt is being made to conserve all the water possible.

Because of the saturated soil in the mountains and recent snowfall in the higher altitudes it is expected that water will be available for spreading for many weeks.

amounts of water they were called upon to control. Numerous quantities of moving sand, gravel and boulders together with floating debris made diversion of water practically impossible even on those systems where the diversion works were capable of handling the flow.

Even though diversion could have been accomplished the existing spreading system would not have been sufficient to prevent floods below. For example, on San Antonio Creek a peak flow of 25,000 cfs. was reported and there are only 1100 acres of land set aside for spreading purposes. Using an absorption rate of 1 in.-12, for given area of a total of 1100 acres it can be seen that the spreading grounds were entirely inadequate to handle a flood of this size.

As the flood receded, spreading which was possible proved to be of value by eliminating the flow across highways and lands in the valleys permitting repair work to start sooner than it could have otherwise.

Damage to spreading areas occurred by the stream breaking out of their normal channel across the debris cones and creating new channels. During the flood it was noted that a new channel would form on the debris cone and this would then become partially filled by debris causing the stream to again seek a different channel as it moved down the cone. This spreading of the flood decreased in wavelets and deposition of debris on portions of the area set aside for spreading and damaged many of the structures. However, on most of the debris cones there still remain portions of the spreading system which can be utilized and spreading was started shortly after the flood had passed. Repair work is already under way and every attempt is being made to conserve all the water possible.

Because of the saturated soil in the mountainous and recent alluvium in the higher altitudes it is expected that water will be available for spreading for many weeks.

An accurate estimate of the damage or cost of repair to some of the spreading systems cannot be made until the areas are resurveyed. New channels may make the existing diversion canals and structures of no value and require an entirely new distribution system to be constructed.

Upper Santa Ana River (San Bernardino County)

At the mouth of the Santa Ana Canyon a peak flow of 45,000 Sec.-ft. was reported. The diversion works for the spreading grounds were undamaged. No water was spread during the storm but spreading was started on March 8th. The attendant stated that unless warm rains melted the recent snow in the mountains it was expected that water would be available for spreading here until Fall.

The upper portion of the spreading grounds was not damaged greatly, but in the lower section where the ditch system was used and Plunge Creek joins the river the area was cut badly and many of the ditches filled with debris by the river and Plunge Creek overflowing their banks. In this section the soil is sandy with no boulders and as a result it is difficult to maintain any permanent works. The damage is estimated to be \$5000.

As the river was joined by Mill Creek, Lytle Creek and other streams it increased in volume and overflowed in many places causing the failure of several highway and railroad bridges.

Mill Creek (San Bernardino County)

Pedley Walls were washed out and the estimated cost of rebuilding is \$30,000. Diversion weirs were temporary and failed. Estimated cost of building larger and more permanent weir is \$50,000.

An accurate estimate of the damage or cost of repair to some of the spreading system cannot be made until the area is surveyed. How channels may make the existing diversion canal and structures of no value and require an entirely new distribution system to be constructed.

Upper Santa Ana River (San Bernardino County)

At the mouth of the Santa Ana Canyon a peak flow of 15,000 Sec.-ft. was reported. The diversion works for the spreading grounds were unchanged. No water was spread during the storm but spreading was started on March 25th. The observations stated that unless warm rains melted the recent snow in the mountains it was expected that water would be available for spreading here until Fall.

The upper portion of the spreading grounds was not damaged greatly, but in the lower section where the ditch system was used and Pimlico Creek joins the river the area was cut badly and many of the ditches filled with debris by the river and Pimlico Creek overflowing their banks. In this section the soil is sandy with no boulders and as a result it is difficult to maintain any permanent works. The damage is estimated to be \$5000.

As the river was joined by Mill Creek, Lytle Creek and other streams it increased in volume and overflowed in many places causing the failure of several highway and railroad bridges.

Mill Creek (San Bernardino County)

Beddy Falls were washed out and the estimated cost of rebuilding is \$30,000. Diversion works were temporary and failed. Estimated cost of building larger and more permanent weir is \$20,000.

Lower Santa Ana River (Orange County)

At the Orange County line a peak flow of 80,000 to 90,000 Sec.-ft. was reported, and in the coastal area the river broke through protection levees flooding large areas, mostly on the west side. The Santiago reservoir on Santiago Creek above Irvin park is credited with preventing serious damage in the city of Santa Ana. Five thousand Sec.-ft. is reported to have passed over the spillway.

Gauging stations on the Chapman Avenue and Yorba Bridges were lost. The stations on the Anaheim-Olive and Jefferson Street bridges were damaged but not beyond repair. Certain sections of the Yorba and Jefferson Street bridges were washed out.

Dikes forming the Anaheim Spreading System near the intersection of Placentia and Orangethorpe roads in Orange County failed by overtopping. Carbon Creek overflowed its banks above and entered the basins adding to the water diverted from the Placentia area. The outlet structures were inadequate to control this flow and the lower dike was washed out. Some silting occurred in the basins. A flume and weir used to measure the inflow and outflow to one of the units were destroyed. Estimated cost of repairing \$2000.

The spreading system in the river bed of the Santa Ana River consisted primarily of temporary ditches on sand bars with no permanent structures. The cost of replacing these ditches was not obtainable but would probably be small.

At the Orange County line a peak flow of 80,000 to 90,000 cfs. was reported, and in the coastal area the river broke through protection levees flooding large areas, mostly on the west side. The Santa Ana River at Santa Ana Creek above Irwin Park is credited with preventing serious damage in the city of Santa Ana. Five thousand cfs. is reported to have passed over the spillway.

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Estimated cost of replacing \$2000. The spreading system in the river bed of the Santa Ana River consisted primarily of temporary ditches on sand bars with no permanent structures. The cost of replacing these ditches was not obtainable but would probably be small.

Devils Canyon (San Bernardino County)

Basins were undamaged. A new channel was cut around diversion weirs and now water is being spread. Diversion works should be rebuilt. Banks will be necessary along the west side of the flood channel to direct water weirs and divert to spreading basins.

Waterman - Twin Creek (San Bernardino County)

The Waterman and Twin Creek spreading grounds were damaged to some extent but not severely. Washouts occurred around the ends of several of the dikes forming basins. The spreading weir across the channel about one mile below the basins functioned throughout the storm. Sections of the paved protection wall failed.

Lytle Creek (San Bernardino County)

Considerable damage was done on the Lytle Creek spreading system by the stream cutting around the west end of Diversion No. 1 and in general following the old flood channel which passes through spreading areas Nos. 1, 2 and 4. This channel is clearly shown on Plate 7 of U. S. D. A. technical Bulletin No. 578 "Spreading Water for Storage Underground" which is an air photo of the Lytle Creek system taken prior to the flood.

The damage to the "Sinking" ditches is estimated to be 90%, 50%, 40% and 20% for areas Nos. 1, 2, 4, and 6 respectively. Diversion Canals to these areas were damaged considerably.

The protection levees between diversion weirs 1 and 2 and 2 and 3 were totally destroyed. This occurred by erosion both from the flood channel and from the back side. Levee No. 4 which extends from weir

Devils Canyon (San Bernardino County)

Basins were damaged. A new channel was cut around diversion weirs and no water is being spread. Diversion works should be rebuilt. Banks will be necessary along the west side of the flood channel to direct water weirs and direct to spreading basins.

Washburn - Twin Creek (San Bernardino County)

The Washburn and Twin Creek spreading grounds were damaged to some extent but not severely. Washburn occurred around the ends of several of the dikes forming basins. The spreading weir across the channel about one mile below the basins functioned throughout the storm. Sections of the paved protection wall failed.

Lytle Creek (San Bernardino County)

Considerable damage was done on the Lytle Creek spreading system by the stream cutting around the west end of Diversion No. 1 and in general following the old flood channel which passes through spreading areas Nos. 1, 2 and 4. This channel is clearly shown on Plate 1 of U. S. D. A. Technical Bulletin No. 778 "Spreading Water for Storage Underground" which is an air photo of the Lytle Creek system taken prior to the flood.

The damage to the "stinking" ditch is estimated to be \$904, 504 and \$204 for areas Nos. 1, 2, 4, and 6 respectively. Diversion canals to these areas were damaged considerably. The protection levees between diversion weirs 1 and 2 and 2 and 3 were totally destroyed. This occurred by erosion both from the flood channel and from the back side. Levee No. 4 which extends from weir

No. 3 to weir No. 4 on the west bank was about 50% destroyed mainly due to cutting from the back side. The water which cut around weir No. 1 apparently tried to reenter the flood channel along this section.

On the east side of the flood channel the spreading areas are on a Mesa and were not seriously damaged. The diversion canals were filled with debris and some cutting occurred on the land adjacent to the flood channel. Recently completed debris basins at the No. 1 weir and on area No. 3 were completely destroyed.

The diversion weirs, gates and flumes were apparently only slightly damaged. Cutting occurred to some extent on the lower side of the weirs but not badly. Considerable deposition took place above weir No. 1.

The main flood channel between the weirs was widened and scoured of all islands, brush and debris by the flood, thereby increasing the capacity considerably for future use. Total cost of system was \$665,000 and is estimated to be about 50% damaged.

Deer Creek (San Bernardino County)

The spreading grounds on Deer Creek cone were apparently only slightly damaged. Considerable debris, however, was deposited around the head works and diversion made impossible. Boulders and other debris were deposited around the diversion gates to a height nearly level with the top of the diversion structure. There is evidence that some water passed over the right bank immediately above the diversion weir but did no great amount of damage. The weir and other structures were not damaged.

By removal of debris at the headworks this spreading system could
with very little water was
be utilized immediately. However, on March

No. 5 to weir No. 1 on the west bank was about 50% destroyed mainly due to cutting from the back side. The water which cut around weir No. 1 apparently tried to reenter the flood channel along this section. On the east side of the flood channel the spreading areas are on a level and were not seriously damaged. The diversion canals were filled with debris and some cutting occurred on the land adjacent to the flood channel. Recently completed debris basins at the No. 1 weir and on area No. 5 were completely destroyed.

The diversion weirs, gates and flumes were apparently only slightly damaged. Cutting occurred to some extent on the lower side of the weirs but not badly. Considerable deposition took place above weir No. 1. The main flood channel between the weirs was widened and scoured of all islands, brush and debris by the flood, thereby increasing the capacity considerably for future use. Total cost of system was \$665,000 and is estimated to be about 50% damaged.

Peor Creek (San Bernardino County)

The spreading grounds on Peor Creek were apparently only slightly damaged. Considerable debris, however, was deposited around the head works and diversion made impossible. Boulders and other debris were deposited around the diversion gates to a height nearly level with the top of the diversion structure. There is evidence that some water passed over the right bank immediately above the diversion weir but did no great amount of damage. The weir and other structures were not damaged.

By removal of debris at the headworks this spreading system could be utilized immediately. However, on March 11th very little water was

crossing Highland Avenue indicating that most of the flow was sinking naturally in the flood channel.

Cucamonga Creek (San Bernardino County)

The Cucamonga spreading grounds were less damaged than any of the places where attempts were made to spread during the flood. With the exception of one, the cross walls of wire and rock construction in the upper section of the system were not damaged. Most of the basins were filled, however, with sand, gravel and other debris.

The wire-rock wall running diagonally across the channel served its purpose by diverting the flood beyond the capacity of the spreading grounds to the flood channel. Due to an inadequate flood channel, the small basins bordering it were all washed out on the channel side. The lower diversion weir was not of sufficient capacity to pass the peak flow and the water broke around one end, cutting a channel across measuring flume No. 1 and causing damage to other spreading structures.

On March 8 the entire flow was being spread permitting the repair of highway structures below.

Estimated damage amount to \$30,000. However, considerable work should be done on main and diversion channels which may cost several thousand dollars.

San Antonio Creek (San Bernardino and Los Angeles Counties)

Severe damage was done along San Antonio Creek, all the way from Ice House Canyon at an elevation of 47000 feet to the point where it entered the Santa Ana River.

A large portion of the spreading grounds was rendered useless by the stream cutting around the diversion works and across other structures

crossing Highland Avenue indicating that most of the flow was striking naturally in the flood channel.

Chocoma Creek (San Bernardino County)

The Chocoma spreading grounds were less damaged than any of the places where attempts were made to spread during the flood. With the exception of one, the cross walls of wind and rock construction in the upper section of the system were not damaged. Most of the basins were filled, however, with sand, gravel and other debris.

The wire-rope wall running diagonally across the channel served its purpose by diverting the flood beyond the capacity of the spreading grounds to the flood channel. Due to an inadequate flood channel, the small basins bordering it were all washed out on the channel side. The lower diversion weir was not of sufficient capacity to pass the peak flow and the water broke around one end, cutting a channel across measuring three No. 1 and causing damage to other spreading structures.

On March 8 the entire flow was being spread permitting the repair of highway structures below.

Estimated damage amount to \$50,000. However, considerable work should be done on main and diversion channels which may cost several thousand dollars.

San Antonio Creek (San Bernardino and Los Angeles Counties)

Severe damage was done along San Antonio Creek, all the way from San House Canyon at an elevation of 1700 feet to the point where it entered the Santa Ana River.

A large portion of the spreading grounds was rendered useless by the stream cutting around the diversion works and across other structures

and basins. The stream broke into several channels as it passed over the debris cone and caused much damage to citrus groves, dwellings and buildings above and in Claremont. As the flow receded considerable effort was required to divert the water back into its original channel and divert it under highway bridges.

A complete survey of the damage to the spreading grounds is not available although it is known that washouts occurred around each of the diversion weirs. Parts of the spreading system on each side of the flood channel still remain and temporary diversion walls are being constructed so as to utilize these areas as soon as possible. New diversion works will be necessary with considerable bank protection along the flood channel.

Preliminary estimates indicate the cost of repairing the damage in San Bernardino County will be \$134,000. In addition to this re-establishing the east channel and embankment is estimated to cost \$145,000.

In Los Angeles County it is estimated that it will cost \$167,600 for repairs and replacements and \$64,400 for new construction.

Big Dalton Creek (Los Angeles County)

There was some caving but no silting of spreading grounds. No water was spread during the storm. The damage was minor and repairs are estimated to cost \$100. New construction and revision of headworks is estimated to cost \$1000.

Little Dalton Creek (Los Angeles County)

This spreading system was damaged considerably. Repairs to flood channel needed. Estimated cost of building new levee and placing system in operation \$30,000. Spreading grounds silted before storm, and scouring during flood was beneficial.

and basins. The stream broke into several channels as it passed over the debris cone and caused much damage to citrus groves, dwellings and buildings above and in Glendale. As the flow receded considerable effort was required to divert the water back into the original channel and divert it under highway bridges.

A complete survey of the damage to the spreading grounds is not available although it is known that washouts occurred around each of the diversion weirs. Parts of the spreading system on each side of the flood channel still remain and temporary diversion weirs are being constructed so as to utilize these areas as soon as possible. New diversion works will be necessary with considerable bank protection along the flood channel.

Preliminary estimates indicate the cost of repairing the damage in San Bernardino County will be \$15,000. In addition to this cost, maintaining the east channel and embankment is estimated to cost \$125,000. In Los Angeles County it is estimated that it will cost \$187,000 for repairs and replacements and \$64,000 for new construction.

Big Basin Creek (Los Angeles County)

There was some saving but no sitting of spreading grounds. The water was spread during the storm. The damage was minor and repairs are estimated to cost \$100. New construction and revision of headworks is estimated to cost \$1000.

Little Basin Creek (Los Angeles County)

This spreading system was damaged considerably. Repairs to flood channel needed. Estimated cost of building new levee and placing system in operation \$30,000. Spreading grounds filled before storm, and scouring during flood was beneficial.

San Gabriel River (Los Angeles County)

Spreading grounds at the mouth of San Gabriel Canyon were not damaged much, as the river channel was of sufficient size at this point to carry the entire flow released from the reservoirs in the canyon. No attempts were made to spread during the high water.

The estimated cost of replacing the following temporary works: 2 concrete diversion weirs, 3 bridges, roads, levees, outlet structures, and gaging stations, is \$7,100.

Other spreading areas, lower down, where sand bars, low bench land, etc. had been diked or furrowed for spreading were totally destroyed. These were, however, considered as only temporary and the loss was not great. About 7 acres of land were lost at estimated cost of \$2500.

The severity of the storm is demonstrated on this river where flood control reservoirs exist and reasonably accurate measurements of the run-off were obtained.

At the Los Angeles County flood control reservoir No. 1 a peak flow of 95,000 Sec.-ft. is reported to have entered the reservoir whereas the greatest previous flow was 47,000 Sec. -ft. on February 17, 1884. (As given in Bulletin 5 "Flow of California Streams", State of California Division of Water Resources.)

Tujunga Wash (City of Los Angeles)

The Tujunga Spreading Grounds of the Bureau of Water Works and Supply of the City of Los Angeles was constructed in 1931, on Water Bureau property. It was divided into 80 basins 100 feet by 400 feet in plan and 3 feet deep. A dwelling house and garage, for the use of the operation and maintenance

San Gabriel River (Los Angeles County)

Spreading grounds at the mouth of San Gabriel Canyon were not damaged much, as the river channel was of sufficient size at this point to carry the entire flow released from the reservoir in the canyon. No attempts were made to spread during the high water.

The estimated cost of replacing the following temporary works:
2 concrete diversion weirs, 3 bridges, roads, levees, outlet structures, and gating stations, is \$7,100.

Other spreading areas, lower down, where sand bars, low bench land, etc. had been filled or furrowed for spreading were totally destroyed. These were, however, considered as only temporary and the loss was not great. About 7 acres of land were lost at estimated cost of \$2500.

The severity of the event is demonstrated on this river where flood control reservoirs exist and reasonably accurate measurements of the run-off were obtained.

At the Los Angeles County flood control reservoir No. 1 a peak flow of 97,000 Sec.-ft. is reported to have entered the reservoir whereas the greatest previous flow was 47,000 Sec.-ft. on February 17, 1934. (As given in Bulletin 5 "Flow of California Streams", State of California Division of Water Resources.)

Tulare Wash (City of Los Angeles)

The Tulare spreading grounds of the Bureau of Waterworks and Supply of the City of Los Angeles was constructed in 1921, on Water Bureau property. It was divided into 80 basins 100 feet by 100 feet in plan and 3 feet deep. A dwelling house and garage, for the use of the operator and maintenance

crews and storage yard are about in the central part of the basin area. The entire area is adjacent to the west bank of the main flood channel of Tujunga Creek, however, another creek channel runs near the western side of the property. The spreading basins were protected by a levee extending along the eastern side of the property and adjacent to the bank of the main Tujunga channel.

At the peak of the flood the spillway of the Los Angeles County Flood Control District's Big Tujunga Dam was discharging 36,000 second feet, and added to this was the heavy run-off from the Big Tujunga drainage area below the dam, the run-off from the Little Tujunga watershed and the valley run-off below the mouths of the canyons. It is estimated that at least 50,000 second feet must have flowed in the channel above the Spreading Works.

The levee, which had protected the basins for eight years, was overtopped and the flood waters swept through the spreading grounds obliterating all but thirteen (13) basins and washing away equipment and a small out-building. The dwelling house and garage survived, the only damage being the deposit of silt and drift wood over the lawns and adjacent yard and in the garage and the basement of the house. The trunk line and most of the distribution lines are apparently still in as the valves were left open causing numerous "springs" over the area.

The cost of replacing the basins and repairing other damage is roughly estimated at \$25,000.00. Just how soon this reconstruction will be accomplished cannot be stated at present.

cross and storage pond are about in the central part of the basin area. The entire area is adjacent to the west bank of the main flood channel of Tujunga Creek, however, another creek channel runs near the western side of the property. The spreading basins were protected by a levee extending along the eastern side of the property and adjacent to the bank of the main Tujunga channel.

At the peak of the flood the spillway of the Los Angeles County Flood Control District's Big Tujunga Dam was discharging 30,000 second feet, and added to this was the heavy run-off from the Big Tujunga drainage area below the dam. The run-off from the Little Tujunga watershed and the valley run-off below the mouth of the canyon. It is estimated that at least 50,000 second feet must have flowed in the channel above the Spreading Works.

The levee, which had protected the basins for eight years, was overtopped and the flood waters swept through the spreading grounds obliterating all but fifteen (15) basins and washing away equipment and a small out-building. The dwelling house and garage survived, the only damage being the deposit of silt and drift wood over the lawn and adjacent yard and in the garage and the basement of the house. The trunk lines and most of the distribution lines are apparently still in as the valves were left open causing numerous "springs" over the area.

The cost of replacing the basins and repairing other damage is roughly estimated at \$25,000.00. Just how soon this reconstruction will be accomplished cannot be noted at present.

Big Tujunga Creek (Los Angeles County)

Minor damage. Estimated cost of repairing \$700. New construction to develop a spreading ground of 500 second-feet capacity with diversion is estimated to cost \$100,000.

Pacoima Creek (Los Angeles County)

Minor damage. Cost of replacing sand bag levee on diversion weir and install timber skimming weirs estimated at \$625.00.

Present diversion temporary. New construction needed for revision of diversion weir and headworks at a cost of \$20,000. Construction of basins in spreading grounds estimated to cost \$40,000.

Saticoy (Ventura County)

No damage to concrete structures or pipe lines and canals. All control structures on new spreading grounds okay. 1000 feet of levees and approximately 1.5 acres of new spreading ground washed out. Preliminary estimate of cost of repairing levee \$625.00.

Approximately 15 acres of new spreading ground will require cleaning at a cost of \$300.00.

Considerable damage to levees on old spreading grounds, but all control structures are undamaged with the exception of one which was washed away. Damage estimated to levees and one control box \$500.00

Protection work functioned satisfactorily and paid for itself many times during the flood.

One test well and recorder lost.

Santa Paula (Ventura County)

Concrete diversion box and gates washed out. Preliminary estimate of cost of repairing \$250.00. Secondary control held and prevented damage

Big Tujunga Creek (Los Angeles County)

Minor damage. Estimated cost of repairing \$700. New construction to develop a spreading ground of 700 square feet roughly with diversion is estimated to cost \$100,000.

Reaching Creek (Los Angeles County)

Minor damage. Cost of replacing sand bag levee on diversion weir and installing minor skimming weir estimated at \$625.00. Present diversion temporary. New construction needed for revision of diversion weir and headworks at a cost of \$30,000. Construction of basins in spreading grounds estimated to cost \$10,000.

Sagehen (Ventura County)

The damage to concrete structures of pipe lines and canals. All control structures on new spreading grounds okay. 1000 feet of levee and approximately 1.5 acres of new spreading ground washed out. Preliminary estimate of cost of repairing levee \$625.00. Approximately 15 acres of new spreading ground will require cleaning at a cost of \$100,000.

Considerable damage to levees on old spreading grounds, but all control structures are undamaged with the exception of one which was washed away. Damage estimated to levees and one control box \$200.00. Protection work furnished satisfactorily and paid for itself.

Many times during the flood.

One test well and recorder lost.

Santa Paula (Ventura County)

Concrete diversion box and gates washed out. Preliminary estimate of cost of repairing \$250.00. Secondary control held and prevented damage

to spreading ground.

Some silt from hills on East got into basins, which may have to be cleaned before spreading is started. Cannot make definite statement regarding this cleaning until later, but will cost several hundred dollars.

Protection work probably saved this entire spreading ground investment.

Piru (Ventura County)

No damage to any part of this spreading ground pipe lines and control structures.

Protection work prevented some damage to levees on east side of this spreading ground.

New work at diversion, constructed in November, 1937, was undamaged.

Remarks

The high original cost construction on some of the water spreading system is due primarily to the fact that relief labor was used.

In some instances the structures were not built to withstand major floods but were designed to wash out under extreme conditions. Temporary spreading works were built pending permanent construction.

In some instances the percolating capacity of the river cone material has been increased by the erosion caused by the flood. Where scouring of the river channels has occurred the natural recharge to the underground basins is increased.

A summary of cost repairing flood damages is shown in the following tabulation. Some of the estimates do not include the cost protecting flood channels.

to spreading ground.

Some alluvial hills on West side of basin, which may have to be cleaned before spreading is started. Cannot make definite statement regarding this cleaning until later, but will cost several hundred dollars. Protection work probably saved this entire spreading ground investment.

Pine (Ventura County)

No damage to any part of this spreading ground since 1927 and

control structures.

Protection work prevented some damage to levee on east side of

this spreading ground.

New work at diversion, constructed in November, 1927, was damaged.

Remarks

The high original cost construction on some of the water spreading

system is due primarily to the fact that relief labor was used.

In some instances the structures were not built to withstand major

floods but were designed to work out under extreme conditions. Temporary

spreading works were built pending permanent construction.

In some instances the percolating capacity of the river some material

has been increased by the erosion caused by the flood. Where scouring of

the river channels has occurred the natural recharge to the underground

basin is increased.

A summary of cost regarding flood damage is shown in the following

tabulation. Some of the estimates do not include the cost protecting flood channels.

FLOOD DAMAGES WATER SPREADING SYSTEM IN SOUTHERN
CALIFORNIA

Name and Location	System prior to Flood of March 2, 1938		Estimated Cost	
	Estimated original cost	Character	Repairing	Additional or new construction
Upper Santa Ana River	\$300,000.00	Permanent	\$ 5,000	- - - - -
Mill Creek	50,000.00	Temporary	30,000	\$50,000.00
Lower Santa Ana River				
Anaheim	25,000.00	Permanent	5,000	- - - - -
River Bed	- - - - -	Temporary	5,000	- - - - -
Devils Canyon	150,000.00	Permanent	15,000	- - - - -
Waterman-Twin Creek	200,000.00	Permanent	15,000	- - - - -
Little Creek	665,000.00	Permanent	300,000	- - - - -
Deer Creek	100,000.00	Permanent	30,000	116,000.00
Cucamonga	500,000.00	Permanent	134,000	145,000.00
San Antonio				
San Bernardino County	- - - - -	- - - - -	170,000	109,000.00
Los Angeles County	- - - - -	- - - - -	167,600	61,400.00
Big Dalton Creek	- - - - -	- - - - -	100.	1,000.00
Little Dalton Creek	- - - - -	- - - - -	20,000.	10,000.00
San Gabriel River				
Main Basin	- - - - -	Temporary	7,100.	474,000.00
Coastal Basin	(New constr.)	Permanent	- - -	402,900.00
Tujunga Wash	155,000.00	Permanent	25,000.	- - - - -
Big Tujunga Creek	- - - - -	Temporary	700	100,000.00
Pacoima Creek	- - - - -	Permanent	625.	60,000.00
Saticoy	- - - - -	Permanent	1,425.	- - - - -
Santa Paula	- - - - -	Permanent	500	- - - - -
Piru	- - - - -	Permanent	none	- - - - -

FLOOD DAMAGES WATER SPREADING SYSTEM IN SOUTHERN CALIFORNIA

Name and Location	System prior to Flood of March 2, 1938	Estimated Cost
Upper Santa Ana River	Permanent \$5,000.00	5,000.00
Mill Creek	Temporary 30,000.00	30,000.00
Lower Santa Ana River	Permanent 25,000.00	25,000.00
Anaheim River bed	Temporary 2,000.00	2,000.00
Devils Canyon	Permanent 15,000.00	15,000.00
Whitman-Twin Creek	Permanent 200,000.00	200,000.00
Lytle Creek	Permanent 65,000.00	65,000.00
Deer Creek	Permanent 100,000.00	100,000.00
Guadalupe	Permanent 150,000.00	150,000.00
San Antonio	Permanent 170,000.00	170,000.00
San Bernardino County	Permanent 107,000.00	107,000.00
Los Angeles County	Permanent 1,000.00	1,000.00
Big Belton Creek	Permanent 10,000.00	10,000.00
Little Belton Creek	Permanent 7,000.00	7,000.00
San Gabriel River	Permanent 125,000.00	125,000.00
Main Basin	Permanent 102,900.00	102,900.00
Coastal Basin	Permanent 1,000.00	1,000.00
Trojunga Wash	Permanent 100,000.00	100,000.00
Big Trojunga Creek	Permanent 60,000.00	60,000.00
Passion Creek	Permanent 1,000.00	1,000.00
Sedley	Permanent 200.00	200.00
Santa Paula	Permanent 200.00	200.00
Pin	Permanent 200.00	200.00

APPENDIX II

Section 5c

Storm of February 26 - March 3, 1938

ESTIMATED FLOOD DAMAGE TO RESERVOIRS
AGRICULTURAL AND URBAN AREAS

By

R. A. Floyd
Soil Conservation Service
and
Phillip Webster
Bureau of Agricultural Economics

APPENDIX II

Section 50

Storm of February 20 - March 5, 1938

ESTIMATED FLOOD DAMAGE TO RESERVOIRS
AGRICULTURAL AND URBAN AREAS

By
R. A. Floyd
Soil Conservation Service
and
Philip Webster
Bureau of Agricultural Economics

ESTIMATED FLOOD DAMAGE CAUSED BY FLOOD
OF MARCH 3, 1938

(Los Angeles, San Bernardino, Riverside, Orange, and Ventura Counties)

The American Red Cross reports 74 persons lost their lives, 116 were injured, and 20 persons are missing as a result of the flood. Approximately 8,300 families suffered losses, 3,800 buildings were damaged, 830 buildings were destroyed, and 4,900 families are in need of assistance.

Public services were disrupted for periods ranging from a few minutes up to several days. The principal damage in the stricken area was to highways, roads, streets, bridges, flood control works, homes, their furnishings, and to automobiles. Public utilities such as railroads, telephones, and electric power systems also suffered heavy damage through washing out of tracks, bridges, 'phone and transmission lines. The damage reported for industrial enterprises was relatively small and principally affected the production of oil companies in Los Angeles and Ventura counties.

The urban areas suffered the most damage because of their location, in many instances, on the streams and flood-fans. The loss of agricultural top-soil and the damage due to deposition of eroded materials on agricultural land was heavy. This type of damage was greatest and most widespread in Ventura and Orange counties while in Los Angeles county the urban damage and loss of life was greatest.

Following is a list of estimated damages secured from public and private officials in the flooded area. To date it has been impossible to obtain estimates on some specific items principally private property, such as: commercial and industrial enterprises, homes and personal property. Estimates of agricultural damages, particularly those due to erosion, are still very incomplete.

This Table Includes Estimates up to and Including March 30, 1938

Estimates of Public and Private Officials for Specific Items

Upper watersheds (chiefly improvements in the National Forest exclusive of roads)	\$ 900,000
Debris basins, flood control dams, reservoirs, channels	8,312,000
Water spreading grounds	932,000
Water supply and distribution works	1,750,000
Agricultural land, crops, livestock, farm improvements (exclusive of erosion)	3,650,000
Federal, state, county and city highways, roads, bridges	19,915,000
Municipal properties (other than streets and bridges)	790,000
Public utilities: telephone, R. R. (not including S. P.) street railways, gas and electric utilities	4,675,000
Industrial and manufacturing enterprises (chiefly oil)	500,000
Homes, personal property, automobiles, etc.	6,500,000
TOTAL	\$ 47,924,000

Estimate of All Damages (principally to private property)

<u>not included in Estimates Given for Specific Items above</u>	\$ 35,000,000
	\$ 82,924,000

Known Dead 74 Known Missing 20 Known Injured 116

ESTIMATED FLOOD DAMAGE CAUSED BY FLOOD
OF MARCH 3, 1938

(Los Angeles, San Bernardino, Riverside, Orange, and Ventura Counties)

The American Red Cross reports 74 persons lost their lives, 116 were injured, and 20 persons are missing as a result of the flood. Approximately 8,300 families suffered losses, 5,800 buildings were damaged, 630 buildings were destroyed, and 14,900 families are in need of assistance.

Public services were disrupted for periods ranging from a few minutes up to several days. The principal damage in the metropolitan area was to highways, roads, streets, bridges, flood control works, homes, their furnishings and to automobiles. Public utilities such as railroads, telephone, and electric power systems also suffered heavy damage through washing out of bridges, pipes and transmission lines. The damage reported for industrial enterprises was relatively small and principally affected the production of all companies in Los Angeles and Ventura counties.

The urban areas suffered the most damage because of their location in many instances, on the streams and flood-plains. The loss of agricultural top-soil and the damage due to deposition of eroded materials on agricultural land was heavy. This type of damage was greatest and most widespread in Ventura and Orange counties while in Los Angeles county the urban damage and loss of life was greatest.

Following is a list of estimated damages secured from public and private officials in the flooded areas. It has been impossible to obtain estimates on some specific items principally private property, such as: commercial and industrial enterprises, homes and personal property, boats, motor vehicles, etc., particularly those due to erosion, are still very incomplete.

This Table includes estimates up to and including March 30, 1938

<u>Estimate of All Damages (originally to private property)</u> <u>not included in Estimates Given for Specific Items above</u>	
\$ 22,921,000	
\$ 37,000,000	
<u>Estimate of Public and Private Officials for Specific Items</u>	
\$ 13,921,000	TOTAL
6,500,000	Homes, personal property, automobiles, etc.
500,000	Industrial and manufacturing enterprises (chiefly oil)
1,675,000	Street railways, gas and electric utilities
790,000	Public utilities: telephone, R. R. (not including U. S. P.)
19,215,000	Federal, state, county and city highways, roads, bridges
2,680,000	(exclusive of erosion)
1,750,000	Agricultural land, crops, livestock, farm improvements
930,000	Water supply and distribution works
8,315,000	Water eroding grounds
\$ 900,000	Public basins, flood control dams, reservoirs, channels
\$ 900,000	Losses exclusive of roads)
\$ 900,000	Open waterways (chiefly improvements in the National

Known Dead 74 Known Missing 20 Known Injured 116

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
CALIFORNIA-NEVADA - REGION 10- HARRY E. REDDICK, REGIONAL CONSERVATOR

Data collected prior to March 22, 1938 - by -
Louis W. Waters - for Ventura County
Carl V. Gragg - Orange and Riverside Counties
Donald C. Johnson - Los Angeles and San Bernardino Counties

MONETARY VALUES OF FLOOD DAMAGES FOR SPECIAL REPORT ON FLOOD DAMAGES
ITEM 5, SUB-ITEM (a) TO (1) INCLUSIVE

DESCRIPTION	Los Angeles County	Orange County	Riverside County	San Bernardino County	Ventura County	Totals for all Counties
SUB-ITEM (a) Watersheds Natural Resources and Improvements						No Figures Available
SUB-ITEM (b) Debris Basins, Flood Control Dams, Reservoirs and Channels.						
Alhambra Storm Drains	\$ 1,200					
Arcadia Storm Drains	100,000					
Azusa Storm Drains	98					
Burbank Storm Drains	3,000					
Claremont Flood Control	5,000					
Culver City Storm Drains	500					
El Monte Storm Drains	5,000					
Gardena Storm Drains	400					
Glendale Storm Drains	15,000					
Glendora Storm Drains	25,000					
Hawthorne Storm Drains	1,000					
Inglewood Storm Drains	1,000					
Long Beach Storm Drains	1,500					
Los Angeles Storm Drains	1,500,170					
Monrovia Storm Drains	5,000					
Montebello Storm Drains	1,500					
Pasadena Storm Drains	950,000					
San Marino Storm Drains	100					
South Pasadena Storm Drains	500					
Sierra Madre Flood Control	13,000					
Whittier Storm Drains	7,500					
Los Angeles County Flood Control	2,464,000					
Dredge West Bank Lytle Creek in Colton				\$ 69,560		
Repair South Bank Santa Ana River in Redlands				28,000		
Mill Creek South Bank Project in Redlands				390,000		
Dredge Warm Creek in San Bernardino				20,000		
Devils Canyon Channel Protection in San B'do.				15,000		
Waterman Canyon Channel Protection in San B'do.				15,000		
Dredge Lytle Creek Channel in San Bernardino				150,000		
Twin Creek Channel in San Bernardino				50,000		
Twin Creek Channel Protection at mouth of canyon				166,000		
Dredge Channels in San Bernardino County				432,355		
Mojave River at Victorville				106,920		
Mojave River at Barstow				81,000		
Santa Ana River South of Colton				153,900		
Chino Creek Channel				10,000		
Franklin Canyon Channel				5,000		
Upper Lytle Creek Channel				13,700		
Mulberry Avenue Channel				34,500		
Cajon Creek Channel				170,000		
All Orange County Flood Control Works		\$ 710,000				

Note: The values shown hereon are for the most part rough estimates obtained from public and private agencies where such data was available; totals apply only for the items shown and do not represent totals for the entire flood area.

UNITED STATES DEPARTMENT OF AGRICULTURE
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MONETARY VALUES OF FLOOD DAMAGES FOR SPECIAL REPORT ON FLOOD DAMAGES

ITEM 5, SUB-ITEM (a) TO (1) INCLUSIVE

DESCRIPTION	Los Angeles County	Orange County	Riverside County	San Bernardino County	Ventura County	Totals for all Counties
Levees on Santa Ana River at Rubidoux Crossing			\$40,000			
Cherry Valley Channels			10,000			
Township Line Ditch			1,000			
Coachella Valley Storm Drains			25,000			
Levees San Jacinto River			<u>15,000</u>			
Santa Clara River					\$400,000	
Ventura River					<u>100,000</u>	
TOTALS SUB-ITEM (b)	\$5,100,468	\$710,000	\$91,000	\$1,910,935	\$500,000	\$8,312,403
SUB-ITEM (c)						
Water Spreading Grounds						
San Antonio Spreading Grounds				\$ 279,000		
Cucamonga Creek Spreading Grounds				317,500		
Deer Creek Spreading Grounds				<u>146,000</u>		
Water Spreading Works Santa Clara River					\$ 1,450	
Totals				\$ 742,500	\$ 1,450	\$ 743,950
SUB-ITEM (d)						
Water Supply and Distribution Works						
Los Angeles County Water System	\$1,200,000					
Monrovia Water System	15,000					
Pasadena Water Mains	45,000					
Sierra Madre Water Mains	<u>500</u>					
Water Works in Orange County		\$ 25,300				
Water Works in Riverside County			\$76,750			
San Bernardino Water Mains				\$ 59,000		
Redlands Filter Plant				12,000		
Private Water Companies, San Bernardino County				250,000		
Colton Water Mains				<u>14,045</u>		
Water Supply City of Ventura					\$ 50,000	
Totals	\$1,261,500	\$ 25,300	\$76,750	\$ 335,045	\$ 50,000	\$1,748,595
SUB-ITEM (e)						
Agricultural Lands						
Los Angeles County	\$ 299,000					
Orange County		\$ 25,000				
Riverside County			\$1,200,000			
San Bernardino				\$ 625,000		
Ventura County					\$1,300,000	
Totals	\$ 299,000	\$ 25,000	\$1,200,000	\$ 625,000	\$1,300,000	\$3,449,000
NOTE: The values shown hereon are for the most part rough estimates, obtained from public and private agencies where such data was available; totals apply only for the items shown and do not represent totals for the entire flood area.						

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MONETARY VALUES OF FLOOD DAMAGES FOR SPECIAL REPORT ON FLOOD DAMAGES

ITEM 5, SUB-ITEM (a) TO (1) INCLUSIVE

DESCRIPTION	Los Angeles County	Orange County	Riverside County	San Bernardino County	Ventura County	Totals for all Counties
<u>SUB-ITEM (f)</u> <u>Rural Non-Agricultural</u>						No Figures Available
<u>SUB-ITEM (g)</u> <u>Urban Property-Private and Public</u>						
Los Angeles County Urban Property	\$15,000,000					
Los Angeles County Parks	304,290					
Bailey Canyon Park	10,300					
Orange County Urban Property		\$13,000,000				
Riverside County Urban Property			\$5,000,000			
Colton Fire Hall				\$ 600		
San Bernardino County Urban Property				\$8,000,000		
Ventura County Urban Property					\$3,500,000	
Totals	\$15,314,590	\$13,000,000	\$5,000,000	\$8,000,600	\$3,500,000	\$
Automobiles - All Counties						500,000
						\$45,315,190
<u>SUB-ITEM (h)</u> <u>Public Utilities</u>						
Alhambra Sewer	\$ 300					
Compton Sewer	500					
Culver City Sewer	2,500					
Glendale Sewer	20,000					
Hawthorne Sewer	16,000					
Long Beach Sewer	1,000					
Los Angeles Sewer	341,850					
Monrovia Sewer	3,000					
Monterey Park Sewer	500					
Pasadena Sewer	2,000					
Sewers outside of Incorporated Cities	2,000					
California						
Nevada/Electric Corporation		\$ 25,000				
California						
Nevada/Electric Corporation			\$ 25,000			
Colton Sewer				\$ 11,000		
Colton Sewage Disposal Plant				4,500		
Colton Street Lights				2,600		
Colton Electric System				300		
San Bernardino Sewers				5,000		
San Bernardino Electric System				15,600		
San Bernardino Outfall Siphon				66,000		
Nevada-California Electric Corporation				25,000		
Power Companies						\$ 577,000
Gas Companies						239,000
Steam Railroads (excludes So.Pac.R.R.)						3,375,000
Street Railroads						275,000
Telephone Companies						150,000

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MONETARY VALUES OF FLOOD DAMAGES FOR SPECIAL REPORT ON FLOOD DAMAGES

ITEM 5, SUB-ITEM (a) TO (1) INCLUSIVE

DESCRIPTION	Los Angeles County	Orange County	Riverside County	San Bernardino County	Ventura County	Totals for All Counties
TOTALS SUB-ITEM (h)	\$ 389,650	\$ 25,000	\$ 25,000	\$ 130,000		\$ 5,185,650
<u>SUB-ITEM (1)</u>						
City, County and State Highways, City Streets, Bridges						
Los Angeles County Bridges	\$ 682,500					
Los Angeles County Highways	924,000					
General Clean-up - County areas	130,000					
Alhambra Streets	1,000					
Alhambra Clean-up	1,000					
Arcadia Streets Clean-up and Bridges	20,000					
Azusa Highways and Clean-up	785					
Burbank Streets, Bridges and Clean-up	22,000					
Claremont Highways and Clean-up	245,000					
Compton Highways and Clean-up	2,000					
Culver City Highways and Clean-up	5,000					
Gardena Bridges, Streets, and Clean-up	2,600					
Glendale Streets and Clean-up	125,000					
Glendora Bridges, Streets, and Clean-up	11,500					
Hawthorne Streets and Clean-up	5,500					
Hermosa Beach Streets and Clean-up	2,200					
Inglewood Clean-up	1,000					
LaVerne Clean-up	3,100					
Long Beach Bridges	3,000,000					
Long Beach Streets and Clean-up	55,000					
Los Angeles Bridges	2,610,530					
Los Angeles Highways	1,331,166					
Los Angeles Clean-up	1,194,872					
Monrovia Bridges	30,000					
Monrovia Streets and Clean-up	23,000					
Montebello Streets and Clean-up	10,000					
Monterey Park Streets and Clean-up	4,000					
Pasadena Bridges	158,000					
Pasadena Streets	140,000					
Pasadena Clean-up	70,000					
Pomona Streets and Clean-up	15,000					
Redondo Beach Streets and Clean-up	250					
San Gabriel Streets and Clean-up	400					
San Marino Streets and Clean-up	800					
San Fernando Streets and Clean-up	6,000					
Santa Monica Streets and Clean-up	5,000					
Sierra Madre Bridges	12,500					
Sierra Madre Streets and Clean-up	15,200					
Signal Hill Streets and Clean-up	150					
South Gate Bridges	110,000					
South Gate Streets and Clean-up	2,500					
South Pasadena Clean-up	200					
Torrance Streets and Clean-up	700					
West Covina Streets and Clean-up	500					
Whittier Streets and Clean-up	1,000					
Orange County		\$ 500,000				

NOTE: The values shown hereon are for most part rough estimates, obtained from public and private agencies where such data was available; apply only for the items shown not represent totals for the entire flood area.

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MONETARY VALUES OF FLOOD DAMAGES FOR SPECIAL REPORT ON FLOOD DAMAGES

ITEM 5, SUB-ITEM (a) TO (1) INCLUSIVE

DESCRIPTION	Los Angeles County	Orange County	Riverside County	San Bernardino County	Ventura County	Totals for All Counties
Riverside City Streets			\$ 25,000			
Riverside County First District			49,900			
Riverside County Second District			36,000			
Riverside County Third District			7,000			
Riverside County Fourth District			21,450			
Riverside County Fifth District			<u>22,000</u>			
Colton Streets				\$ 100,000		
Mt. Vernon Ave. Bridge, San Bernardino				20,000		
South Arrowhead Bridge, San Bernardino				3,000		
Second Street Bridge, San Bernardino				30,000		
Third Street Bridge, San Bernardino				3,000		
Cuttle Drive Bridge, San Bernardino				3,500		
City Streets, San Bernardino				24,000		
"K" Street Bridge, San Bernardino				50,000		
"I" Street Bridge, San Bernardino				50,000		
"G" Street Bridge, San Bernardino				50,000		
Valley Street Bridge, San Bernardino				30,000		
Clean-up Streets of Rialto				12,000		
San Bernardino County Highways and Bridges				<u>745,000</u>		
Ventura County City Streets					\$ 70,000	
Ventura County Highways and Bridges					<u>1,320,000</u>	
Totals	\$10,854,953	\$ 500,000	\$ 161,350	\$ 1,120,500	\$ 1,390,000	\$18,026,803
SUB-ITEM (j) Industrial, Manufacturing Developments						No Figures Available
SUB-Item (k) Commercial Property						
Los Angeles County Oil Companies	\$ 120,000					
Orange County Oil Companies		\$ 80,000				
Ventura County Oil Companies					\$ 190,000	
Ventura County Rock and Pipe Companies					<u>100,000</u>	
Totals	\$ 120,000	\$ 80,000			\$ 290,000	\$ 490,000
GRAND TOTALS	\$33,340,161	\$14,365,300	\$6,554,100	\$12,864,580	\$7,031,450	\$83,271,593
SUB-ITEM (1) Loss of Life						
Los Angeles County	25					
Orange County		19				
Riverside County			2			
San Bernardino County				Dead 11 Missing 17		
Ventura County					3	
Totals						Dead 60 Missing 17
NOTE: The values shown hereon are for the most part rough estimates, obtained from public and private agencies where such data was available; totals apply only for the items shown and do not represent totals for the entire flood area.						

CALIFORNIA

HIGHWAYS AND PUBLIC WORKS



*Main Line Railroad Bridge across Los Angeles River
Wrecked by Flood*

Official Journal of the Department of Public Works
APRIL • 1938

CALIFORNIA HIGHWAYS AND PUBLIC WORKS

Official Journal of the Division of Highways of the Department of Public Works, State of California

EARL LEE KELLY, Director C. H. PURCELL, State Highway Engineer JOHN W. HOWE, Editor K. C. ADAMS, Associate Editor

Published for information of the members of the department and the citizens of California

Editors of newspapers and others are privileged to use matter contained herein. Cuts will be gladly loaned upon request.

Address communications to California Highways and Public Works, P. O. Box 1499, Sacramento, California.

Vol. 16

APRIL, 1938

No. 4

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Disastrous Winter Floods Caused \$8,000,000 Damage to State Highways and Bridges

THREE separate storms during the period December 11 to March 4, damaged State highways and structures to the extent of \$8,000,000.

December and February storms took their heaviest toll in the northern part of the State, while the March storm concentrated on the southern section. The damage for the entire period, however, was almost equally divided between the two areas.

December and March storms, which caused over 90 per cent of the damage, were of three to five days duration and brought rains of cloudburst proportions to the higher altitudes, while establishing record-breaking hourly and daily precipitation records in the valley and coastal regions.

The March storm, which this article describes, swept in from a low-pressure area over the Pacific which extended from the Aleutian Islands south to a point about 800 miles west of San Francisco. Los Angeles, Orange, Riverside, Ventura, and San Bernardino counties suffered the brunt of its attack.

TORRENTIAL RAINS

Heaviest rains centered in the San Bernardino and San Gabriel mountains, northerly of San Bernardino and Pasadena, where a total of 30.49 inches for the storm was recorded at Lake Arrowhead, and 10.89 inches during an 8-hour period at Camp Opids in the upper reaches of the San Gabriel. The city of Los Angeles reported 11.06 inches for the storm, 5.55 inches of which fell within a 24-hour period on March 2.

The rainfall data clearly indicate the increasing precipitation as the storm neared the mountains. For instance, Long Beach reported some 6.99 inches of rain for the storm period; Huntington Park 9.48 inches; Los Angeles 11.06 inches; and Azusa 14.95 inches. Again, Newport Beach reported 5.95 inches; San Bernardino 9.82 inches; Devils Canyon 13.65 inches; Waterman Canyon 22.10 inches; and Lake Arrowhead 30.49 inches. The counties of Santa Barbara and San Luis Obispo to the north of the storm center, as well as San Diego to the south, shared to a lesser degree in the storm damage.

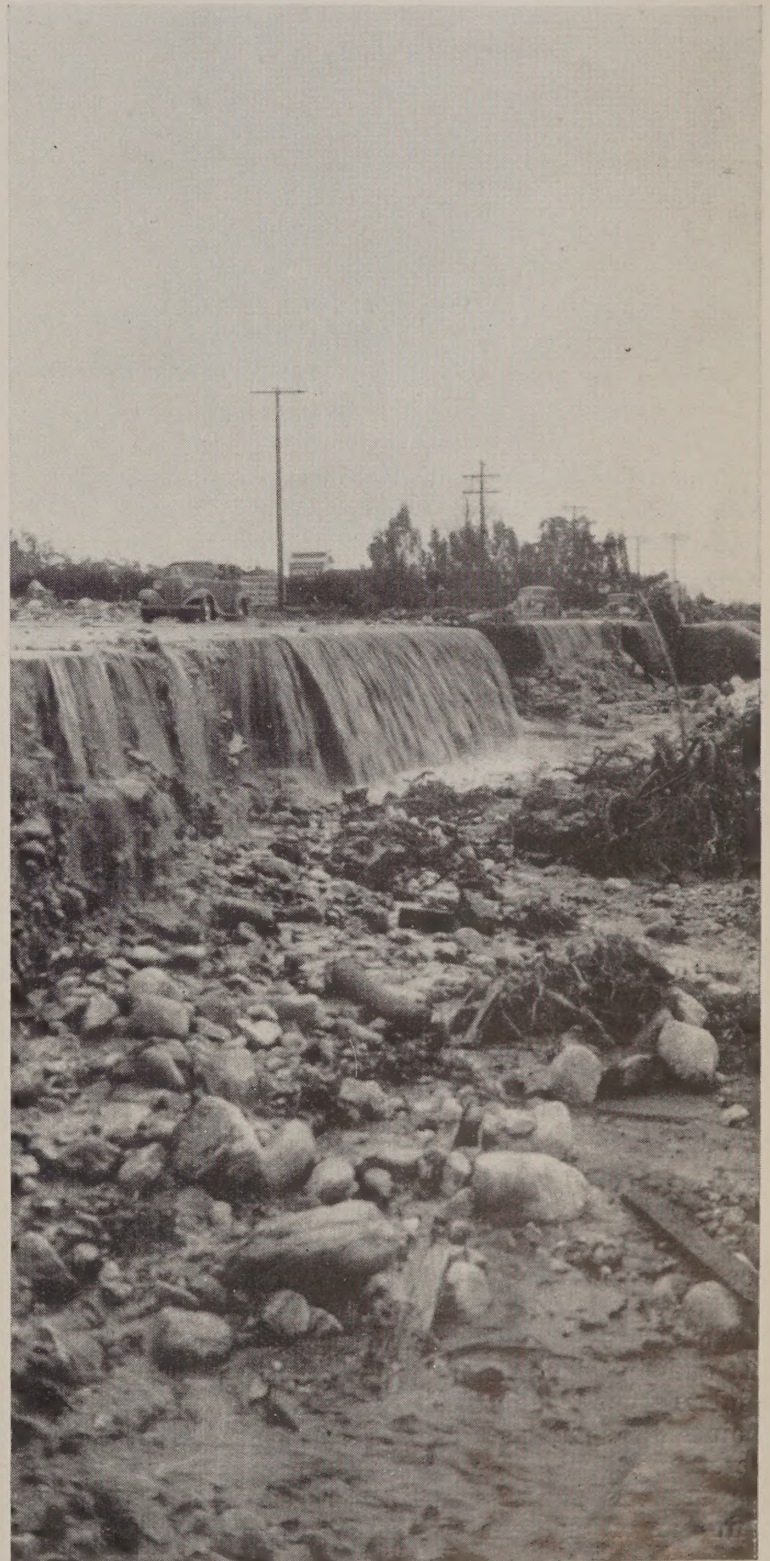
RIVERS LEAVE BANKS

The effect of this downpour was immediately evident. The normally dry stream beds on these mountain slopes, tributary to the Santa Clara, San Gabriel, Santa Ana, Mojave and Whitewater rivers, were soon raging torrents. The main rivers, swollen to flood proportions by this sudden influx, overtopped their banks, creating flood conditions unprecedented since 1884. In the resulting chaos, lives were lost, property destroyed and lines of communication and transportation either damaged or disrupted.

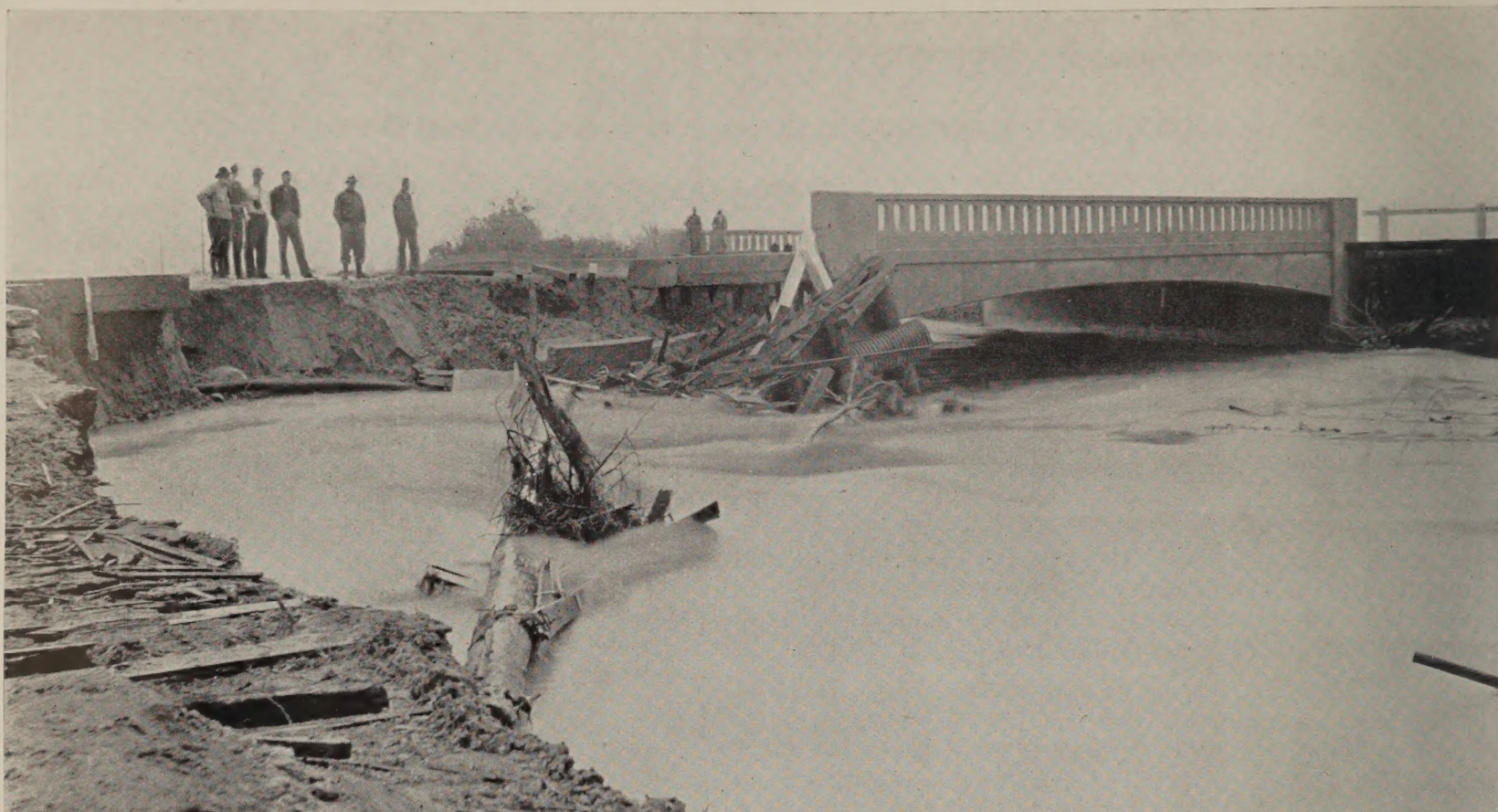
In such a battle no quarter is asked or given. Failures of services under such conditions deserve no censure, as the law of economics must govern man's constructive efforts. There remained, however, the supreme test upon which judgment will always be passed; namely, the ability to recover and function under such punishment.

March Storms Took Big Toll

By T. H. DENNIS
Maintenance Engineer



Waterfall on Foothill Boulevard in San Bernardino County caused by flood waters of Cucamonga Creek.



High waters in Barton Wash ripped away timber wing on this bridge on Route 168-C in Los Angeles County.

When it is known that, within two days after the storm, travel was again moving over many of our highways—even though mountains had moved, bridges washed out, and pavements and embankments slipped away—you will acknowledge that the highway forces had justified their ideals of organization and service.

Men and equipment—owned and rented—were worked without stint from the time the storm broke, so that relief might be forthcoming when the danger was past. Had not this been done, the disrupted rail lines, telephone and telegraph service, as well as the broken gas mains, might still be under repair lacking the opportunity of reaching the damaged areas.

Long lines of buses plied the highways transferring railroad passengers around damaged tracks and bridges, to their destination. Trucks loaded with poles and wire were in constant evidence on our roads, speeding out to repair and replace the lines. At one time the telephone, telegraph and teletype communication to coast points was so drastically congested or interrupted that the Federal Communications Commission lifted a certain ban on amateur radio operators

to supply this service. The gas companies at several locations utilized bridge structures to hang temporary gas mains pending their permanent replacement.

WHERE DAMAGE OCCURRED

The storm, as previously mentioned, dealt with varying severity throughout the southern counties. In order that its effect and attendant problems may be visualized, a brief account is given of what happened to our highways in each district.

A glance at the maps, in which is indicated in solid dark portions the various kinds of damage, will also prove enlightening. (Pages 7 and 11.)

In District VIII

Beginning with District VIII, which includes Riverside and San Bernardino counties, the heaviest damage occurred on the highways leading to the Lake Arrowhead, Big Bear Lake and Barton Flats resort areas; on the Highland, Foothill, Valley and Mission boulevards westerly of San Bernardino; and on the highways in the vicinity of Palm Springs, as well as on the National Old Trails Highway at Cajon Pass and Barstow.

Lytle Creek, joined by the waters of Cajon Creek at the base of the mountains, was responsible for the great damage suffered by San Bernardino and Colton. Overtopping its banks north of Highland Avenue, State Route 190, the water proceeded southerly, tearing out homes and auto courts as well as claiming several lives, until it reached Foothill Boulevard, State Route 9. Here the river poured into one of its old channels, completely covering the highway and isolating San Bernardino from Los Angeles; also, tearing out the steel bridge of the Santa Fe Railroad and the approaches to the bridge of the Pacific Electric Interurban Railroad.

SAN BERNARDINO HIT

The flood waters following the main channel continued through the southwest portion of the city of San Bernardino, ripping out bridges and homes, until they reached the vicinity of the famous National Orange Show building, where they destroyed auto courts, covered the highway with silt to a depth of six feet, and washed out some 1800 feet of our embankment on Route 26 at the southerly entrance to San Bernardino. At this point, Lytle and Warm creeks joined in their rush to the Santa Ana River,

forming a half-mile wide channel which completely covered highways and farms.

The waters of Lytle Creek, which broke over into one of its overflow channels, raged through the easterly portion of Colton, closing our Route 26. By this time, Lytle Creek and its tributary side canyons had washed out portions of the Cajon Pass and damaged the Verdemont Subway on Route 31. Here, too, it washed out or buried the Union Pacific and Santa Fe's mainline tracks with sand, rock, and debris. Effecting complete isolation, it also washed out the Pacific Electric and Southern Pacific lines.

SANTA ANA RIVER RAMPAGES

The Santa Ana River, originating in the mountains at the easterly end of San Bernardino Valley, picked up new life from large side canyons and reached a peak flood stage at Orange Avenue, State Route 190, north of Redlands.

All road crossings above this point were washed out. Here the river spread northward, inundating one mile of our highway. Further south it breached the southerly approach fill to the highway bridge on Route 26 at the south entrance to San Bernardino, washing it out for a width of 150 feet. There, joined by both Lytle and Warm creeks, it overtopped the fill of the highway on Route 26 connecting the cities of Redlands and Colton. Approximately 600 feet of this fill was carried away, but the three bridges there remained undamaged.

On its way westward, the Santa Ana crossed Highway Routes 43, 19, 193, and 77 in District VIII. Only two of the structures on these routes succumbed to the flood—one at Norco on Route 193, the other at Prado on Route 77. The Norco structure was completely destroyed. This was an obsolete bridge, posted for weight restriction, which was taken into the State System in 1933 by legislative action. The Prado structure, like that at Norco, was county-constructed and

Praise from South

March 18, 1938

Mr. Earl Lee Kelly, Director
Department of Public Works,
Public Works Bldg.,
Sacramento, California.

Dear Earl:

Yesterday I made the round trip from San Diego to Los Angeles going up via Capistrano through Anaheim and returning in the evening down the Coast Route.

I was absolutely both amazed and surprised at the work which the State Highway Department has done in such a short time, following the storm, returning these highways back to such a splendid condition for traveling. It is certainly a wonderful testimony to you as head of the Department of Public Works, your associates and the maintenance men in the Highway Department for their ability and speed in keeping the highways open and making them passable under such extraordinary conditions. **MORE POWER TO YOU.**

With kind personal regards,
I am

Yours very truly,

H. E. RHOADES, President,
The San Diego Club

Below—Views of the Santa Ana River at the State Highway Bridge on the Los Angeles-San Diego route (U. S. 101) near the city of Santa Ana taken before and during the peak of the flood. The bridge was not damaged.

taken into the system by legislative action.

All State-constructed bridges over the Santa Ana River in District VIII, as well as the two county-constructed bridges over Routes 43 and 190, withstood the flood.

MOJAVE RIVER OUT OF BED

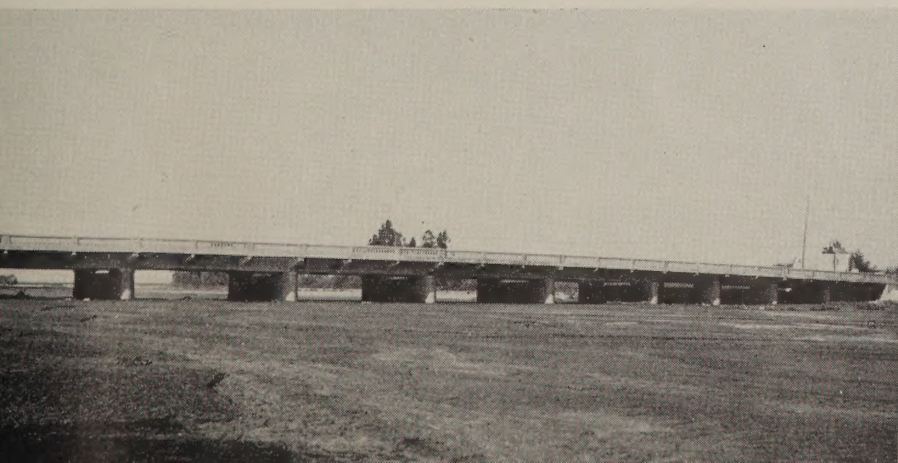
While the Santa Ana River, Lytle Creek, Warm Creek and their tributaries were wreaking havoc in and around San Bernardino, Colton and Riverside, the Mojave River—which runs through the Mojave Desert to empty into Cronese Valley and Soda Lake at Baker—was doing its share of heavy damage.

At the narrows, southerly of Victorville, the tracks of the Santa Fe and Union Pacific railroads were washed out and all bottom lands inundated. At Barstow the river went completely out of its channel, around historic Buzzard Rock north of the town, destroying some 6000 feet of our highways on State Routes 31 and 59. At Baker on Route 31, the junction with Route 127 to Death Valley, flood waters doubled the width of the channel and tied up all traffic.

North of San Bernardino, the "Rim of the World Drive"—our Routes 43, 59 and 189—to Lake Arrowhead and Big Bear was severely damaged by slides and slipouts. Saturated to plastic state by some 30 inches of rainfall, high embankments settled and moved down the canyons, while sections in cuts folded together, closing miles of these roads.

TONS OF DEBRIS

Westerly of San Bernardino, Cucamonga Wash and San Antonio Wash tore out sections of Highland Avenue, Foothill Boulevard, Valley Boulevard and Mission Boulevard—our State Routes 190, 9, 26 and 19. These washes, heading back in the mountains, overtopped their banks and deposited thousands of yards of debris and boulders upon the highways, blocking all traffic. Owl Creek Wash, east of Banning, left its banks, carry-





Scenes of Highway Damage by March Storm in Southern California

1. Shoulder washed out and pavement undermined on State Highway 26 by flood waters of Santa Ana River near San Bernardino city limits.
2. Canton Creek usually a placid little stream went wild and tore out a large section of embankment and pavement of Ridge Route Alternate near Piru Gorge.
3. A raging flood rushed down from the San Bernardino Mountain range through Cajon Canyon washing out a large section of the National Old Trails Highway (U. S. 66) in Cajon Pass.
4. Normally an insignificant stream, Placerita Creek whirled with mighty force around a bend and scoured out over 10,000 cubic yards of the Newhall-Saugus highway in Los Angeles County.
5. Warm Creek rose out of its banks and cut a new channel that entirely washed away a portion of State Highway No. 26 between Redlands and Colton.
6. Another large section of the Ridge Route Alternate in Los Angeles County was washed out when Piru Creek scoured away paved slopes.
7. San Antonio Wash crossed the Foothill Boulevard near the west San Bernardino County line destroying shoulders and pavement and depositing a mass of large boulders.





8



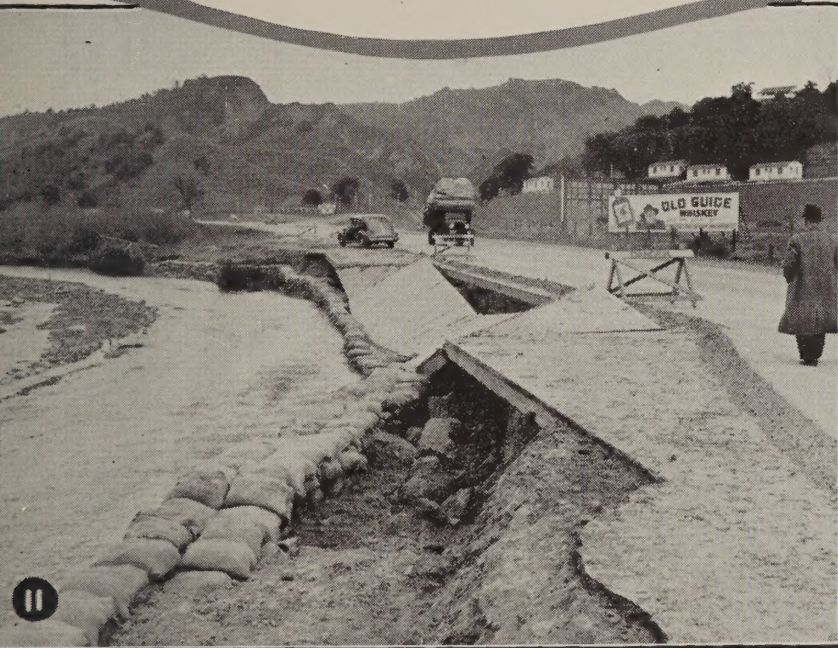
9

Raging Streams Obliterated Many Miles of Roadway and Pavement

8. Lytle Creek inundated areas in vicinity of Colton in San Bernardino County leaving autos stuck in silt on State Highway 26.
9. Rushing through Santa Ana Canyon in Orange County, the Santa Ana River changed its course and washed out State Highway construction that will cost more than \$100,000 to restore.
10. Garapito Creek coursing through Topanga Canyon in Los Angeles County gouged out a large portion of Highway 156.
11. Small streams from the slopes of the Santa Susana Mountains made a wild torrent of Gavin Creek that destroyed part of Route 4 in Weldon Canyon.
12. The Big Tujunga Wash which crosses the route of State Highway 9 near Sunland wreaked destruction on roads and bridges.
13. Embankment was washed out together with half the Newhall-Saugus highway when a creek became a river.
14. The flood roaring down Santa Monica Canyon joined with high-ocean waves to undermine the Coast Highway at the canyon's mouth.



10



11



12



14

ing away portions of Routes 26 and 187, which lead to Palm Springs and the Coachella and Imperial valleys.

Farther east Whitewater River, after crossing Route 26, left its old channel, destroying a considerable section of the Southern Pacific's main line track to the east. Snow Creek, joined by the Whitewater River, washed out approaches to Snow Creek Bridge on Route 187, as well as long stretches of this highway between there and Palm Springs, virtually isolating the town.

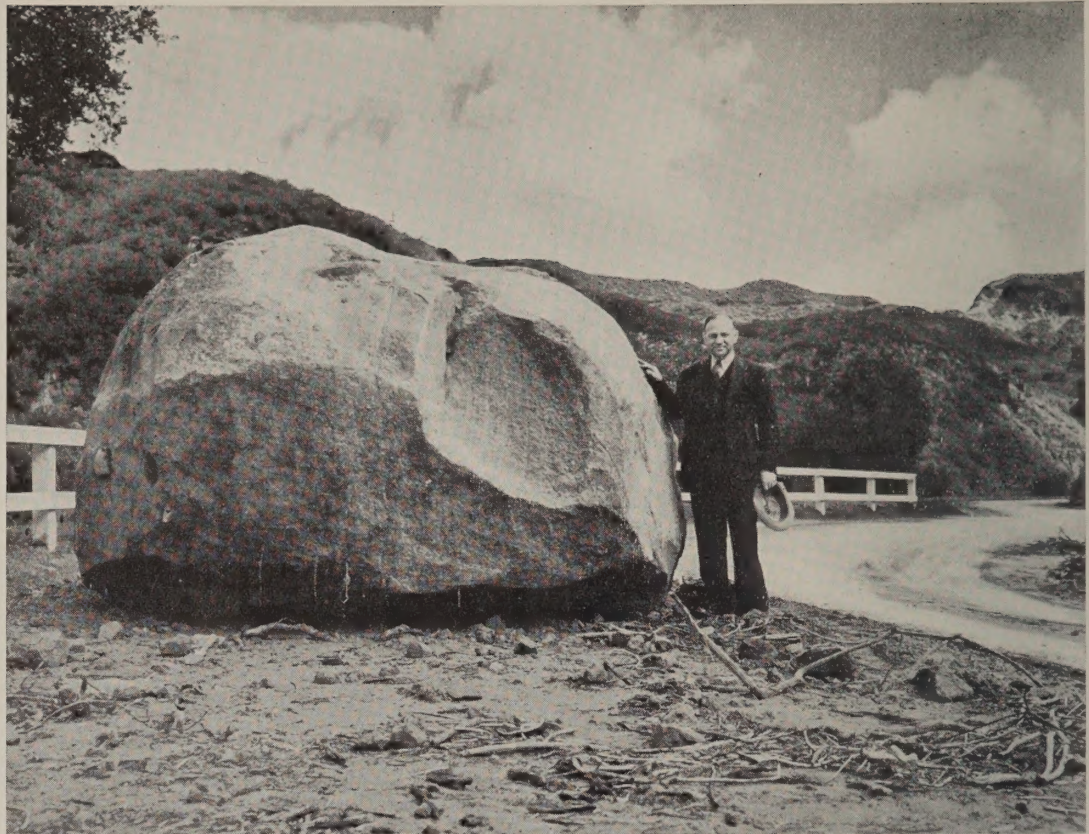
In spite of the heavy damage, traffic was again moving over the greater number of these highways within a few days following the storm. It will require weeks, however, to restore many of those highways in the mountain areas to a safe traversable condition. In this district alone 215 trucks, 44 graders, 48 tractors, 29 power shovels and 1 pile driver, besides hundreds of men, were immediately placed on the restoration of the roads. Of this equipment, 122 of the trucks, 29 of the tractors, 7 of the graders, the power shovels and pile drivers had to be rented. Since competitive bids were required, it may readily be seen how effectively the district was organized.

In District VII

District VII, embracing Ventura, Los Angeles and Orange counties, received the first brunt of the storm as it came from the ocean, then its recoil as the floods rushed seaward back from the mountains. The San Juan, Santa Ana, San Gabriel and Santa Clara rivers covered the highways, destroying approaches, undermining the bridges, and in places carrying away large sections of roadbed. Here was a test for the district whose roads served half of the State's population and vehicles. That it was met, and in a remarkably short time, redounds to the District's credit. A brief resume of the extent of this problem now follows:

DESTRUCTIVE FLOOD WATERS

The Santa Ana River, fresh from its destruction of the Prado Bridge in District VIII, entered the canyon leading to Olive. On its way it washed out some 3000 feet of heavy roadbed construction and portions of three county-constructed bridges on State Routes 176, 175 and 181. Leav-



Upper—Huge boulder deposited by flood on Topanga Canyon Road below Wildwood, Los Angeles County. Lower—Mud cleared from highway near east city limits of Colton, San Bernardino County.

ing the canyon, it spread wide over the highways and orchards, damaging everything in its path. Forced back to its channel south of Placentia, it again took its toll of the bridges. First and last on our highways were the Garden Grove structure on Route 179 and that north of Newport Beach

on Route 60. At the former, it took out the westerly approach, making a new channel; and at the latter location it undermined piers, dropped four of the spans, and washed out some 2000 feet of the pavement.

This was the only State-constructed bridge lost on the Santa



Locations of State Highway damage in Los Angeles, Ventura and Orange counties marked by black blocks on roads. Legend explains necessary restoration work.

Ana, though no reflection is intended on those which failed when the river bed was churned to unknown depths by the turbulent flood. Within a week's time travel was again using the canyon, and pile trestles and detours have now closed the gap in the coast route.

SANTA CLARA RIVER CURBED

Once before the Santa Clara pushed its wall of water through the foothill towns of Piru, Fillmore and Santa Paula, leaving a trail of death in its wake. The Saint Francis Dam disaster taught its lesson, and though that former crest was equalled, the material loss this time can fortunately be repaired.

The Santa Clara, on its westward way, crosses Route 4—our Ridge Route—and parallels Route 79, crossing State Routes 155, 9 and 2 where it enters the ocean. On Route 4 it scoured the north approach to the highway structure, undermining the pavement. Proceeding westerly, it carried away 300 feet of the Bardsdale Bridge southerly of Fillmore on Route 155, and 500 feet of the structure on Route 9 at Saticoy.

Nearing the ocean, it swept wide of its banks covering orchards and farm lands and filling the El Rio Subway on Route 60 with sand and debris.

East of Piru, on Route 79, its sharp swing into the bank carried away 3000 feet of the roadway.

BRIDGES RIPPED OUT

While this was taking place, its tributaries—Castaic and Sespe creeks—flowing from the north, carried away 200 feet of the bridge west of Castaic, and 800 feet of the Sespe's overflow structure west of Fillmore, effectively closing Route 79. The Sespe hurled the Southern Pacific structure, parallel and adjacent one on the highway, against the latter with such force that it left its moorings and has not been located since.

All of the structures mentioned as damaged were of early county construction and came into the State System under legislative act. Restoration work was immediately initiated, and traffic has now been restored on Routes 79 and 155, pile trestles and fills replacing the washed out structures and roads.

Early reports from the San Gabriel Mountains told of slide-blocked roads and embankments washed down the canyons on Route 62. Similar word was received from Route 138 high in the Santa Barbara National Forest. Here storm-swollen rivers preempted the canyons, carrying with them much of the roadway. Slides for a

time blocked the Ridge Route, but men and equipment soon restored traffic.

The Coast Route 60 from Santa Monica west was covered with slides and debris from the various washes out of the Santa Monica Mountains. Topanga Canyon Route 156 was badly washed and immense slides closed the road to all through traffic. Malibu Bridge piers were undermined and several spans of the structure collapsed. Within a week's time, trestle bents carried the traffic, and power shovels and trucks were repairing the roadway.

Not one of the district's roads, east of a line between Long Beach and Pasadena, escaped damage. Day and night the district's forces labored, clearing debris-covered pavements, restoring protection work and supporting undermined pavements. Regular forces were augmented by some 700 men, 35 power shovels, 150 trucks, 3 pile drivers and other equipment. Within several days after the storm most of the main roads were open to traffic, though months will elapse before all are repaired.

In District XI

District XI, which includes the counties of San Diego, Riverside and Imperial, lay on the outer edge of the storm path. The damage here was less severe, though some 7.86 inches of rain fell near Descanso on March 3d within a 12-hour period. A 9-inch rain at Escondido forced a heavy runoff from Lake Hodges Dam into San Dieguito Creek, whose storm waters undermined the north approach to the San Dieguito Creek Bridge north of Del Mar on Route 2. Traffic was detoured five days while power shovels repaired the break.

The Puerta La Cruz Crossing on Route 78, and the dips at Pala and Pauma Wash on Route 195, were washed away, closing the roads for a period of three days. High water over Route 197 west of Ramona and on Route 198 north of El Cajon, forced the detouring of traffic for short periods.

In Riverside County, two timber trestles over the Coachella Valley Storm Drain on Route 187 were destroyed by high water. These were obsolete structures, taken into the State System by legislative act, and



This is how flood left E Street in San Bernardino, a thoroughfare leading to famous Orange Show Pavilion, which can be seen on the left of power shovel removing five feet of mud.

plans were already under way for their replacement.

In District V

District V, embracing Santa Barbara, San Luis Obispo and Monterey counties, was even more fortunate than District XI, as the storm closed but few of its major highways.

Eleven inches of rain on the San Marcos Pass, State Route 80, during the storm period, caused numerous slides on the east slope, as well as damage to the approaches of Santa Aqueda Creek Bridge. Detours were available and traffic was therefore put to no great inconvenience.

The heavy downpour, however, added many thousands of yards of slides on the Carmel-San Simeon road, State Route 56; the Mustang Grade, State Route 10; and the Pinnacles Road, State Route 119. Eight power shovels and thirty-five trucks are now engaged in clearing these roads.

Truck traffic was held up for a few hours when the Santa Maria River swept over the ground level road in



Overflow waters from Coyote Creek left Firestone Boulevard, Los Angeles, looking like this after being cleared of silt.

the old overflow channel, forcing light traffic to use the old trestle. The heaviest damage occurred on the Cu-

yama Road, State Route 58, where a section of pile trestle was carried away by the flood.



This picture vividly reveals damage wrought by Santa Clara River floods on Ventura-Castaic lateral highway between Piru and Los Angeles County line in Ventura County.

(Continued on page 24)

DAMAGE TO BRIDGES HEAVY

By W. A. DOUGLASS, Associate Bridge Engineer

IN DECEMBER 1937, a series of severe storms swept over Northern and Central California, breaking records for concentrated rainfall and leaving widespread damage both to private and public property. Direct and immediate losses to State highway bridges alone exceeded a half million dollars, and the total cost of repairs and replacement on State highways is estimated at nearly three million.

In turn, Southern California was visited, during the first week of March, 1938, by storms leaving behind property damage many times that of the December storm in the north.

The areas most seriously affected were in Los Angeles, Orange, San Bernardino and portions of Ventura and Riverside counties. Effects of the storm, to a lesser extent, were also felt as far north as Monterey and Fresno counties. Rough preliminary estimates indicate a direct loss of State highway bridges in the March storm of over one and one-half million dollars. The total loss to State highways during this storm has been estimated at over five million dollars.

STREAM CONTROL STUDIES

In addition to the restoration of highways and structures, there will be the cost of new waterway openings and extensive protection work, the need for which became apparent during the recent storm. Extensive studies of the entire area together with the past and probable future behavior of the streams, planned and probable stream control work by other agencies and property owners and a number of other factors must be made before the entire cost may be calculated. The cost of additional bridges, bridge extensions, slope protection and stream control in the immediate vicinity of highway crossings may easily cost a million dollars in addition to the restoration of facilities destroyed by the flood.

The following data will give an idea of the extent and character of the flood damage to State highway

structures. Reports indicate that about forty-five bridges were totally destroyed or seriously damaged. Approach fills were washed out in a number of cases and in three or four locations it appears that extensions to the bridges will be necessary. In at least ten locations entirely new channels were cut across the highway and, in each case it will be necessary either to provide new bridges or return the streams to their former locations.

BRIDGES WIPED OUT

In western Fresno County, Waltham Creek carried a considerable flow. State Route 10 follows this stream closely, westerly from Coalinga, and a number of temporary crossings as well as a county built concrete bridge were damaged.

A timber bridge over the Cuyama River was washed out near the Santa Barbara-San Luis Obispo county line east of Santa Maria.

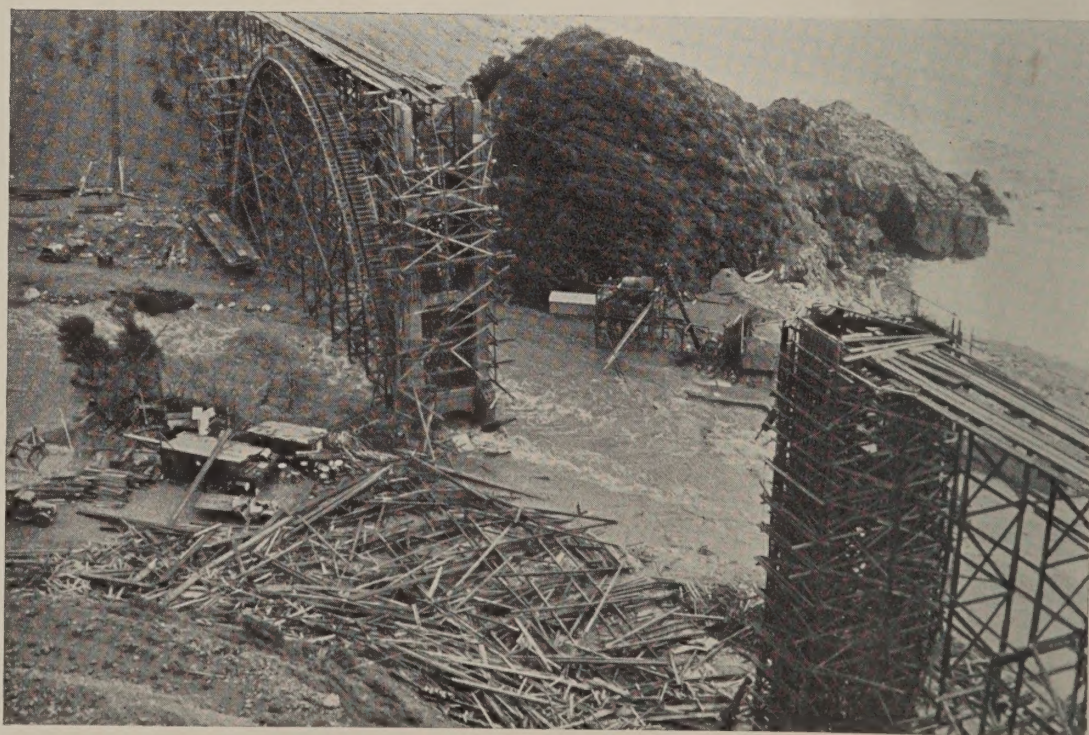
The Santa Clara River flooded taking out portions of two bridges, one crossing the river near Fillmore and the other near Saticoy. These were

both old structures on sections of highway recently taken into the system. It is interesting to note that both these bridges withstood the flood caused by the failure of the San Francisquito Dam in 1927, when a portion of the bridge on the coast highway was destroyed. The latter has since been replaced with a modern structure which was not damaged in the March flood while the two older bridges upstream were seriously damaged.

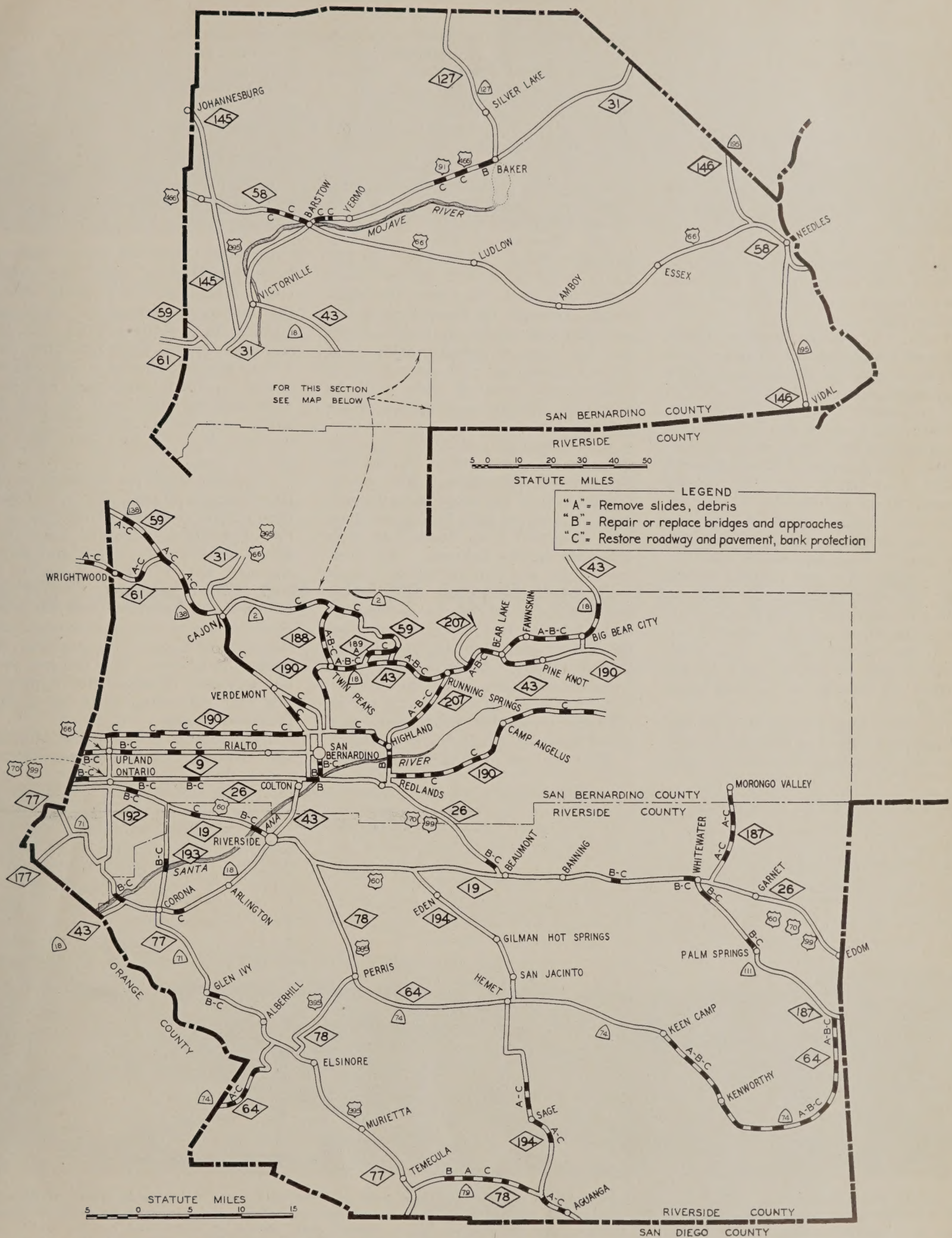
SANTA CLARA RIVER RAMPAGES

In the valley of the Santa Clara River Highway Route 79 was washed out in spots and two bridges were damaged. An old timber structure over the Sespe Creek Overflow at the westerly edge of Fillmore is practically a total loss. Although it is planned to construct a line change and eventually abandon this particular section of road as a State highway, a bridge will be necessary to accommodate through traffic for about one year and it will continue in use permanently for local traffic.

Three spans of another old timber



Bridge under construction across Big Creek on the San Simeon-Carmel coast highway in Monterey County. Concrete piers withstood flood waters but high winds blew down falsework of one arch.



State Highway damage in San Bernardino and Riverside counties marked by black blocks on roads. Legend explains necessary restoration work.

bridge over Castaic Creek just west of the junction of Route 79 with Route 4 were taken out by the high water. This bridge will probably be replaced with a modern type bridge at a slightly higher grade.

SPANS DESTROYED

Three spans of the concrete bridge across Malibu Lagoon, on the Coast Highway above Santa Monica, were lost when heavy scour caused settlement of two piers. This bridge was built by the county about 1923 and later widened to a forty foot roadway by the State.

Further south on the same route, the reinforced concrete bridge near the mouth of the Santa Ana River was damaged in a similar manner. The overflow from this river also washed out a short section of fill a few hundred feet north of the bridge.

Near the junction of Route 60 with Route 2 at Serra, San Juan Creek crosses State Routes 64, 2 and 60. One steel stringer span of a timber and steel bridge on Route 64 was lost. On Route 2 a comparatively new concrete bridge was not injured except that scouring of approach fills resulted in some loss of slope pavement. On Route 60 no damage occurred to the new concrete bridge but additional length of bridge may be advisable to permit more immediate run-off.

Of some fourteen State highway crossings of the Santa Ana River only four are of modern steel or concrete

design and of these four, only one, built about 1925, was damaged. The balance of the Santa Ana bridges were built prior to the inclusion of the routes in the State system. Of the latter group, five bridges were lost or seriously damaged.

In the vicinity of San Bernardino and westerly toward Upland and Pomona, many streams such as the Santa Ana River, Warm Creek, Lytle Creek, Cucamonga Wash and San Antonio Creek, overflowed their banks and in several places established new channels across the highways. Damage by these streams occurred particularly on Routes 9, 26 and 19. New structures, bridge and culvert extensions and extensive protection and control work will be necessary to avoid a repetition of the losses.

It will be noted that this area lies adjacent to the foothills of the San Bernardino Mountains. The sparse forest cover of the mountains permits rapid run-off of rain falling on them with resultant flash floods and high velocities in the canyons. All these conditions are conducive to heavy scour on the steep slopes and the silt and debris is carried to the valleys and plains at the foot of hills where the flatter gradients of the streams permit silting. These silt deposits form debris cones which in this section have built up over a long period of time to sizable proportions and cover areas of many square miles.

The streams ordinarily follow a

course somewhere near the center of the cones and the banks of the channels are usually somewhat higher than the adjacent slopes of the cones. As a result of this condition, the streams at flood stages overflow the banks and spread out over the flat slopes of the cones readily forming new channels in the relatively loose and unstable silt deposit.

DEBRIS CONES

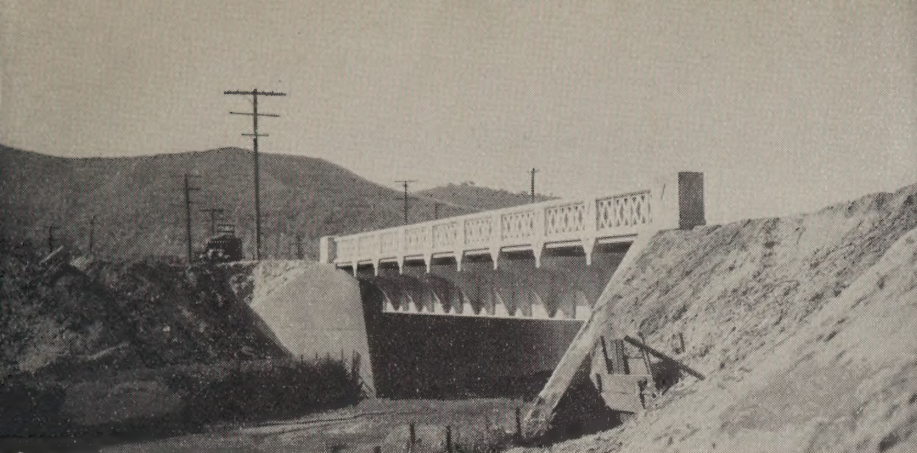
Boulders, drift or other obstructions particularly near the upper ends of the cones may easily deflect the flow to one side or the other and change the entire course of the streams. It was these changing conditions and locations of streams which caused so much damage to east and west highway Routes 9, 26 and 19 which cross several such debris cones between Pomona and San Bernardino.

A similar condition occurred in the Big Tujunga Wash. Route 9 crosses this stream between Pasadena and San Fernando. Bridges were provided for both the north and south channels, both of which seemed to be well defined. However, during the March storm, overflow from the south channel spread out and caused considerable damage to the highway between the bridges. The bridges were not seriously damaged but approach fills and protection work were partially destroyed.

Due largely to the heavy flow in the Tujunga, the Los Angeles River



Sespe Creek swollen out of its banks by tributaries in a high mountain area of Ventura County cut a wide swath of damage as it swept across State Highway 79 near Fillmore. A county-built timber and concrete bridge and a paralleling railroad structure were washed away. A large section of highway was obliterated but a detour road shown at right was quickly built and opened.



Before and after views of the bridge across Verdugo Creek on State Highway 61 in Los Angeles County. Fed by small tributary streams in the San Gabriel Mountains the creek became a raging torrent that cut a new channel, swept away the bridge approach and damaged the abutment.

carried an unusually large run-off. The bridge built by the city over that river on Lankershim Boulevard (Highway Route 159) was lost.

In addition to the Los Angeles-San Bernardino and coastal plain area, floods occurred on the Mojave River, damaging the highways near Barstow, probably necessitating a bridge over at least one new channel and taking out bridges at Cronise Valley and Baker. The Owl Wash and San

Gorgonio Wash east of Banning on Route 26 established new channels which will require bridges and protection work. The Whitewater River at two crossings of Highway Route 187 between Indio and Mecca took out portions of two old timber bridges, one of which was included for replacement in the budget for the present biennium. Smaller bridges were lost also on the "Pines to Palms Road" east of Hemet and on various

routes in the San Bernardino Mountains.

A number of the bridges damaged during the flood are located on Federal Aid Routes and are considered qualified for Federal Emergency Relief funds. The balance of the cost will be financed from State Highway Construction and Maintenance Funds.

STREAMS TEAR OUT HIGHWAYS IN DISTRICT XI

By E. E. WALLACE, District Engineer

The severe rain storm which hit Southern California between February 26 and March 5 did heavy damage to some of the State highways in portions of District XI, which encompasses San Diego, Imperial and the east half of Riverside counties.

On State Route 2, U. S. Highway 101, between San Diego and the northerly county line, there were several incipient failures of bridge approaches due to slumping and erosion of approaches and pot holing around the bridge piers. Protective measures

prevented serious damage or interruption to traffic except at the San Dieguito River Bridge, just north of Del Mar, where 40 feet of the north approach fill slumped out under the footing of the north abutment and between the pilings, due to severe scouring action in front of the abutment.

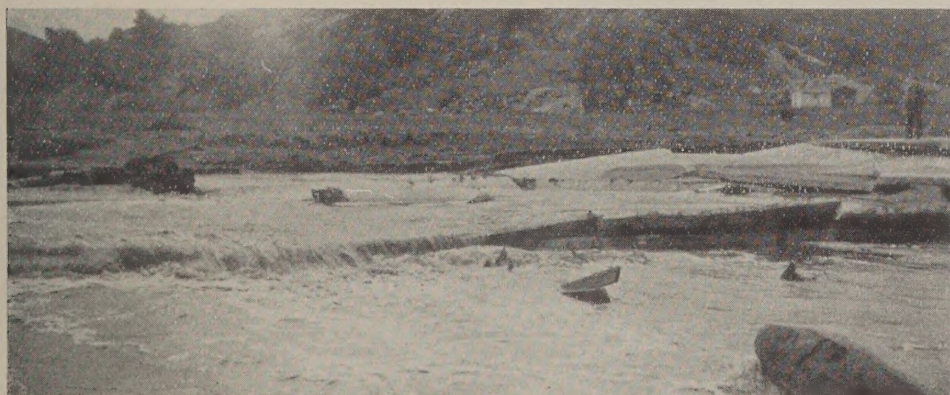
SLIDES AND WASHOUTS

On Route 78, at the Puerta La Cruz crossing of the San Luis Rey River north of Warners Hot Springs, the central 100 feet of an overflow dip

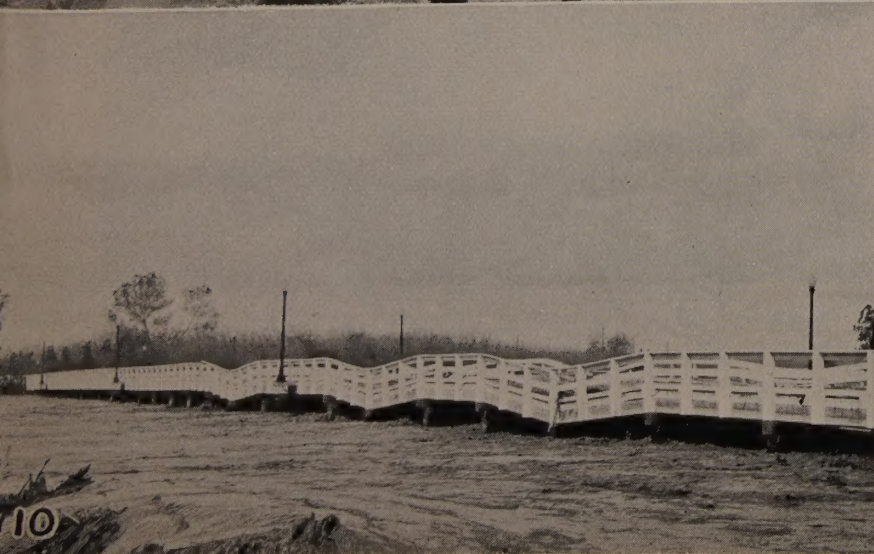
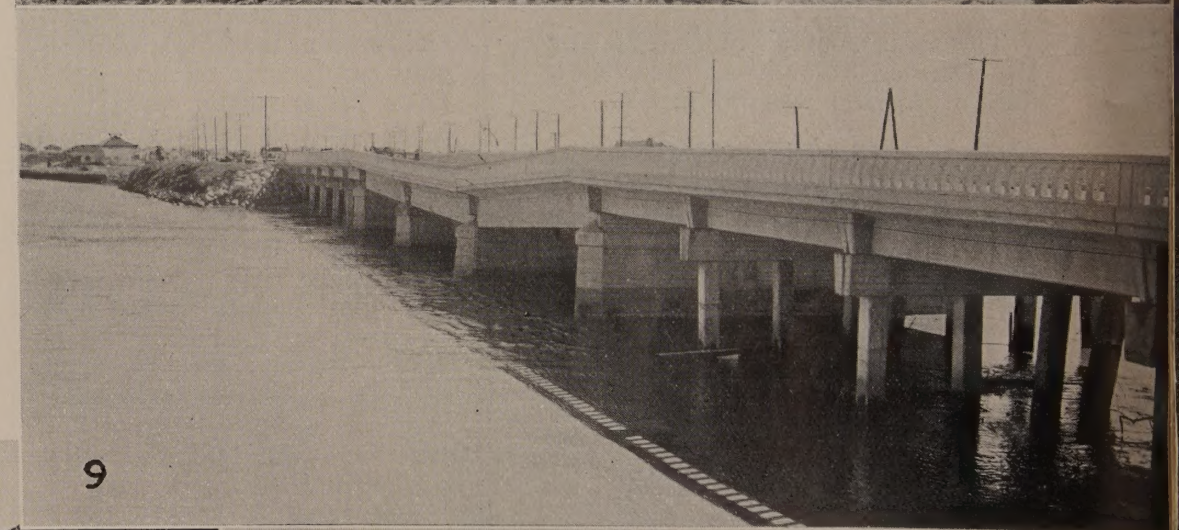
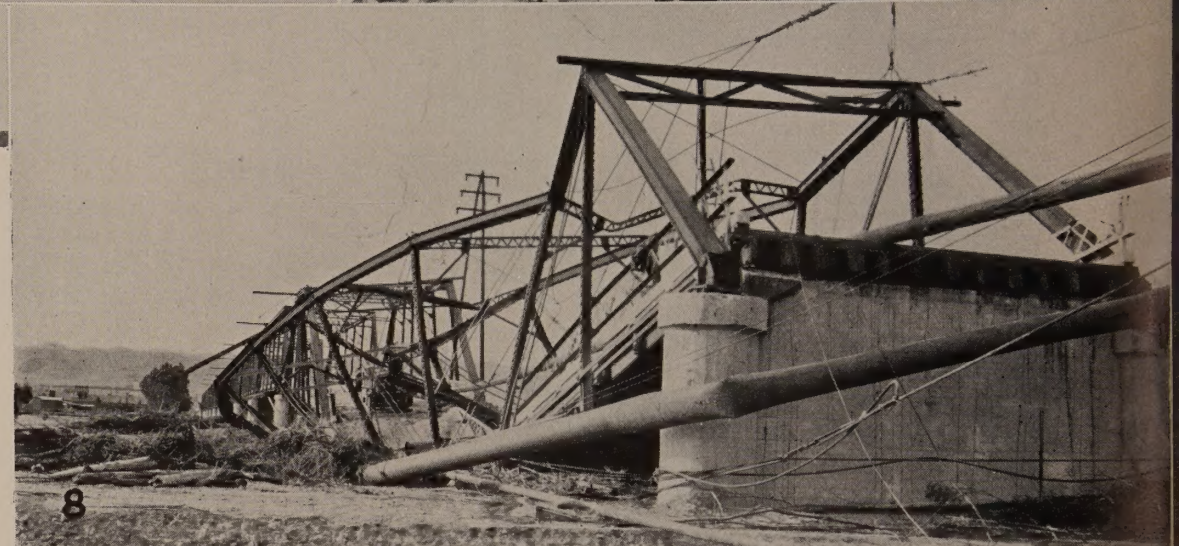
washed out. The dip carried water up to a depth of about five feet, but failed when a peak of more than six feet occurred. Traffic was restored by the construction of a temporary fill after the water subsided sufficiently, three days later.

On Route 195, between Bonsall and Morettis, there were numerous slides and washes, particularly on Cuca Grade, where severe shoulder erosion occurred. At the Pala Dip and Pauma Wash, the shoulders were

(Continued on page 22)



Highway dip washed out by Santa Maria River east of Ramona. Another dip west of Ramona overflowed.



BRIDGES HARD HIT BY FLOODS

- 1—San Antonio Creek Bridge, Ventura County.
- 2—Santa Clara River Bridge near Fillmore.
- 3—Wreckage of bridge across Santa Ana River, Orange County.
- 4—Santa Ana River Bridge east of Colton.
- 5—Sespe Creek Bridge east of Fillmore.
- 6—Big Tujunga Bridge, Los Angeles County.
- 7—Cujama Bridge, 20 miles east of Santa Maria.
- 8—Santa Clara River Bridge, Ventura County.
- 9—Bridge across Santa Ana River near Newport.
- 10—Bridge across Santa Ana River in Santa Ana.
- 11—Santa Ana River Bridge in Santa Ana Canyon.
- 12—Castaic Creek Bridge, Los Angeles County.
- 13—Santa Ana River Bridge near Olive, Orange County.

Snow Removal to Date Totals 100,000,000 Cubic Yards

By W. A. SMITH, Assistant Maintenance Engineer

THE 1937-38 winter season in northern California started in a normal manner with the first snowfall on October 3. The first real storm extended from November 11 to 18.

Typical of the storm periods and the rate of snowfall is the record obtained by District III from the United States Weather Bureau station located three miles west of Donner Summit at Soda Springs on U. S. 40.

Storm Periods	Snowfall During Storm in Inches	Depth of Snow Pack in Inches
1937		
October 3-----	3	---
November 11 to 18-----	53	31
December 10 to 11-----	(10.8 inches rainfall)	---
December 22 to 25-----	24	28
1938		
January 15 to 20-----	48	53
January 31 to		
February 15-----	256	202
March 1 to 3-----	31	138
March 15 to 23-----	63	170

The total snowfall at Norden near the Donner Summit as reported to date of April 1 was 587 inches.

IN OTHER AREAS

The record of snowfall on a few other routes, typical of various areas is as follows:

	Inches
Sign Route 24—East of Quincy-----	208
U.S. 99—Vicinity of Weed-----	132
Sign Route 89—Cayton Valley-----	207
U.S. 299—Fall River-----	195
U.S. 97—Weed to State line-----	207
Sign Route 36—Deer Creek Meadows to Susanville-----	507
Sign Route 36—Paynes Creek to Deer Creek Meadows-----	551
Sign Route 8—At Antelope Springs east of Jackson-----	106
Sign Route 4—At Camp Connell east of Big Trees-----	216
Sign Route 108—At Pinecrest east of Sonora-----	261

The last three points are at the limit of winter maintenance.

The Redding district estimates that some forty million cubic yards of snow was moved by their forces. On the same basis for the other dis-

Snow Removal Crews Lauded

Tahoe, California
Feb. 23, 1938

Mr. C. H. Weeks,
Division of Highways,
Truckee, Calif.

Dear Mr. Weeks:

We do want you to know how very much we appreciate the untiring efforts of yourself and your crew in getting the road open to Tahoe, and feel that this is the sentiment of all in this region. During a storm, many people become panicky, and perhaps you were unduly harassed, but we know that you did all that was humanly possible.

We hope the time will come, and before too long, when a plow can be kept for use in the Lake Tahoe region. The railroad parallels the road over the summit, and can be used in emergency, while we are dependent upon the road being kept open between Truckee and Tahoe. We who have lived here for many years have an emergency supply, but many people nowadays just live from one day to the next, and think they are suffering unless they can have everything a city market affords.

We would like to write a letter, commending the efforts of yourself and your crew, to the higher-ups. To whom should it be addressed to do the most good?

Yours very truly,

(Signed)

Mr. and Mrs. George R. Bliss

tricts, in excess of one hundred million cubic yards of snow has been removed from the highways during the season.

156 PLOWS PROVIDED

In preparation for the work, the Division had purchased nine auger type rotary plows, making a total of twenty-six plows of this type ready for service. In addition to the rotary plows, some one hundred and thirty push plows of various types were made ready for service.

In order to reduce drifting in certain well defined areas, eleven miles of new snow fence was erected, and the fence erected in previous years was repaired or reinstalled at locations where it had been taken down at the end of the 1936-37 winter season.

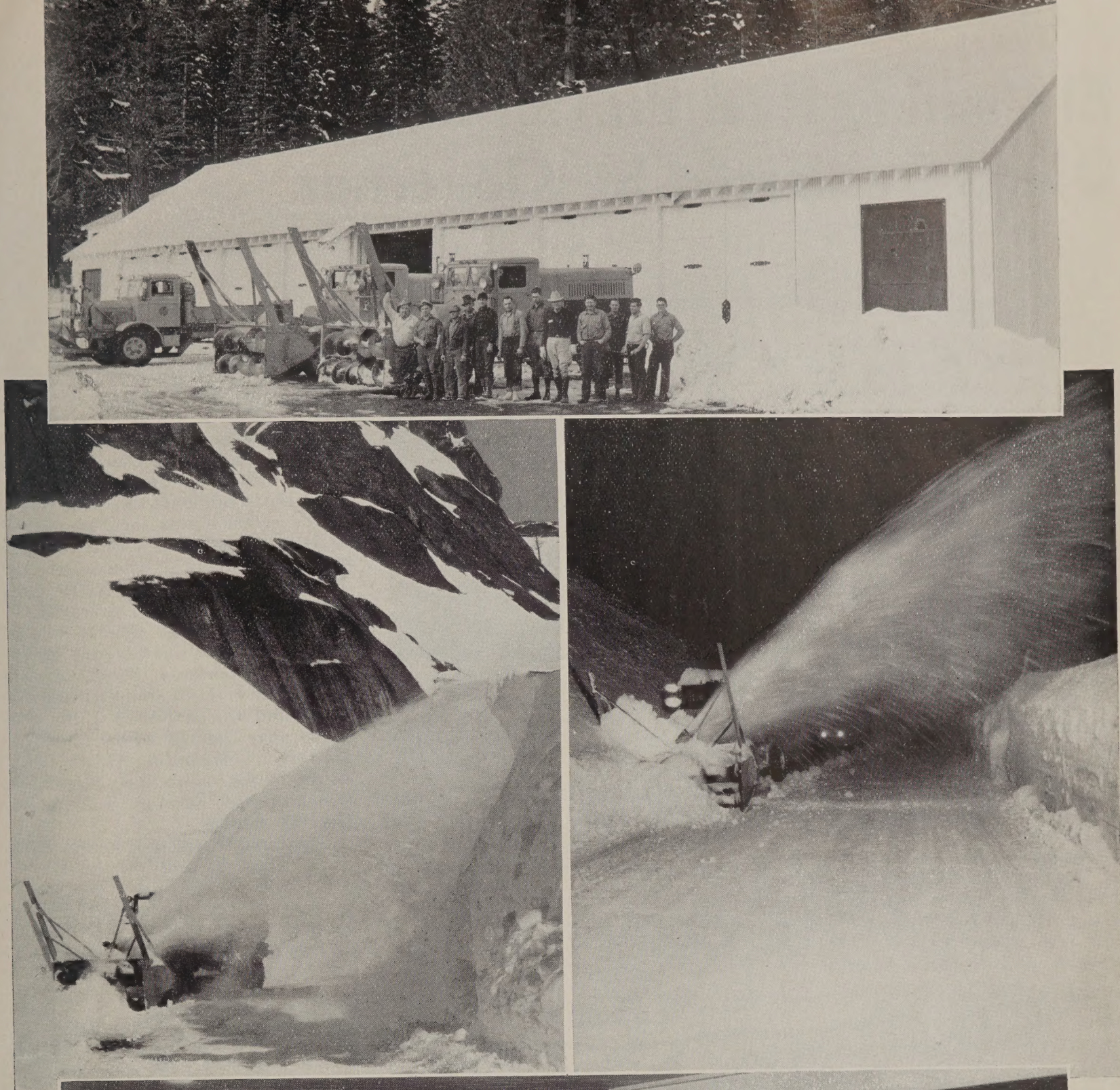
When the season advanced toward the end of January, the department began to feel that this was to be one of those exceptional years. Certain roads, such as U. S. 50 over Echo Summit and many miles of other mountain routes, were still open to travel, a condition that had not existed in any season since snow removal was undertaken.

MANY FALLEN TREES

With the start of the storm on January 31, however, this optimism was quickly dispelled. The snow was heavy but still drifted badly. In certain areas the snow removal was seriously handicapped by the large number of trees that fell into the traveled way. At such times the plows were tied up until a path could be cut and in the meantime the road was becoming filled with drift.

The normal plan in snow removal work in the heavy fall areas is to start the push plows as soon as there is enough snow on the pavement to form a windrow. The rotaries then come along and move this windrow clear of the roadway. Under the conditions encountered, the crews found

(Continued on page 22)



Snow removal crews and equipment. Upper—Maintenance Station Building and crew at Yuba Pass on Donner Summit Highway. Center left and right—Snow plows operating day and night on Donner Summit. Lower—Interior of Donner Summit Maintenance Station showing men and equipment.

El Camino Real Project In San Diego Dedicated by Governor

AS THE setting sun cast a roseate glow over the waters of the Pacific on the evening of Saturday, March 26, Governor Frank F. Merriam stood on the Coast Highway at the San Diego County line north of Oceanside and formally opened and dedicated the \$1,225,000 final link of a multi-lane highway extending for 235 miles from the Mexican border to Santa Barbara on U. S. Route 101.

The ceremonial climaxed a day of fiesta celebration under auspices of the Oceanside and San Clemente chambers of commerce that began with a large official luncheon at the California-Carlsbad Hotel in Carlsbad, which was followed by a radio dramatization of the Romance of El Camino Real at Oceanside Beach stadium and concluded with a coronation ball at San Clemente Casino where Miss Norma Ellis, of Oceanside, queen of San Diego County highways, and Miss Dorothy Walker of San Clemente, queen of Orange



Governor Merriam and Leo Carrillo.

separate opposing streams of traffic and make headon collisions virtually impossible.

Governor Merriam told of the efforts of the early road boosters and builders, of the \$73,000,000 succes-

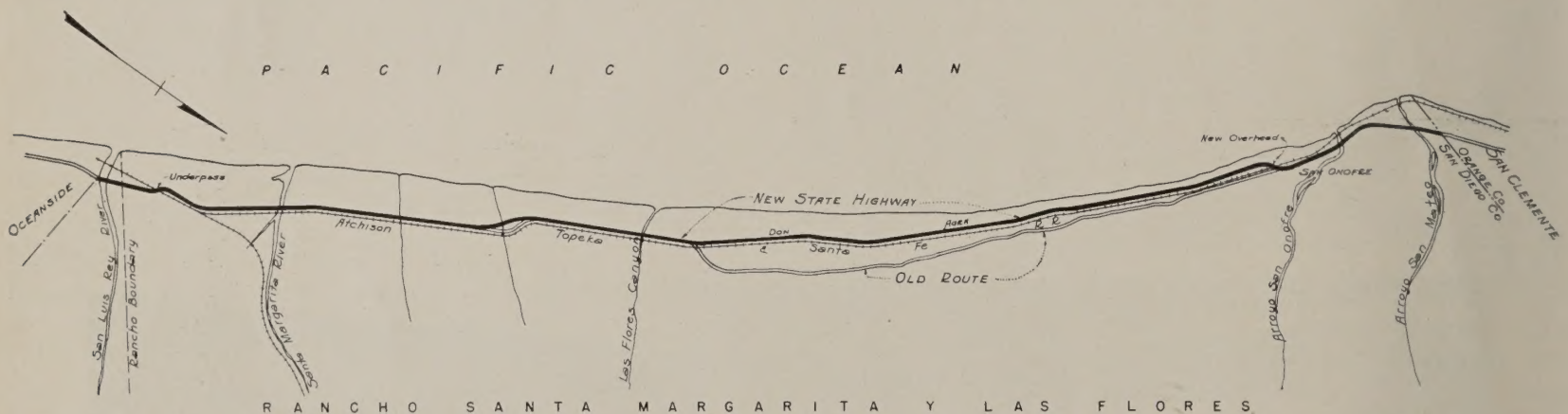
and youth of California both materially and spiritually."

WEDDING OF COUNTIES

Other speakers were State Highway Commissioners William T. Hart and Phillip A. Stanton, Hamilton Cotton, Mayor Albert P. Waibel of Oceanside and Mayor Dan Mulherron of San Clemente. General Chairman E. E. Hyde announced that the theme of the occasion was the "wedding" of Orange and San Diego counties and called upon Assistant Director of Public Works Harry A. Hopkins to perform the nuptial ceremonies.

On the San Diego County side of the boundary line were Mayor Waibel; Supervisor B. A. Sweet; Commissioner Hart, representing the State, and Queen Norma Ellis. On the Orange County side were Mayor Mulherron; Hamilton Cotton, substituting for a county supervisor, Commissioner Stanton and Queen Dorothy Walker.

Assistant Director Hopkins para-



County highways, reigned over the festivities.

In his brief dedication address Governor Merriam said the latest ideas in modern road building had been incorporated in the newly completed 18-mile stretch between San Onofre and Oceanside. The State Highway engineers, he pointed out, had provided two and one-half miles of four-lane divided highway with ample division strips arranged to

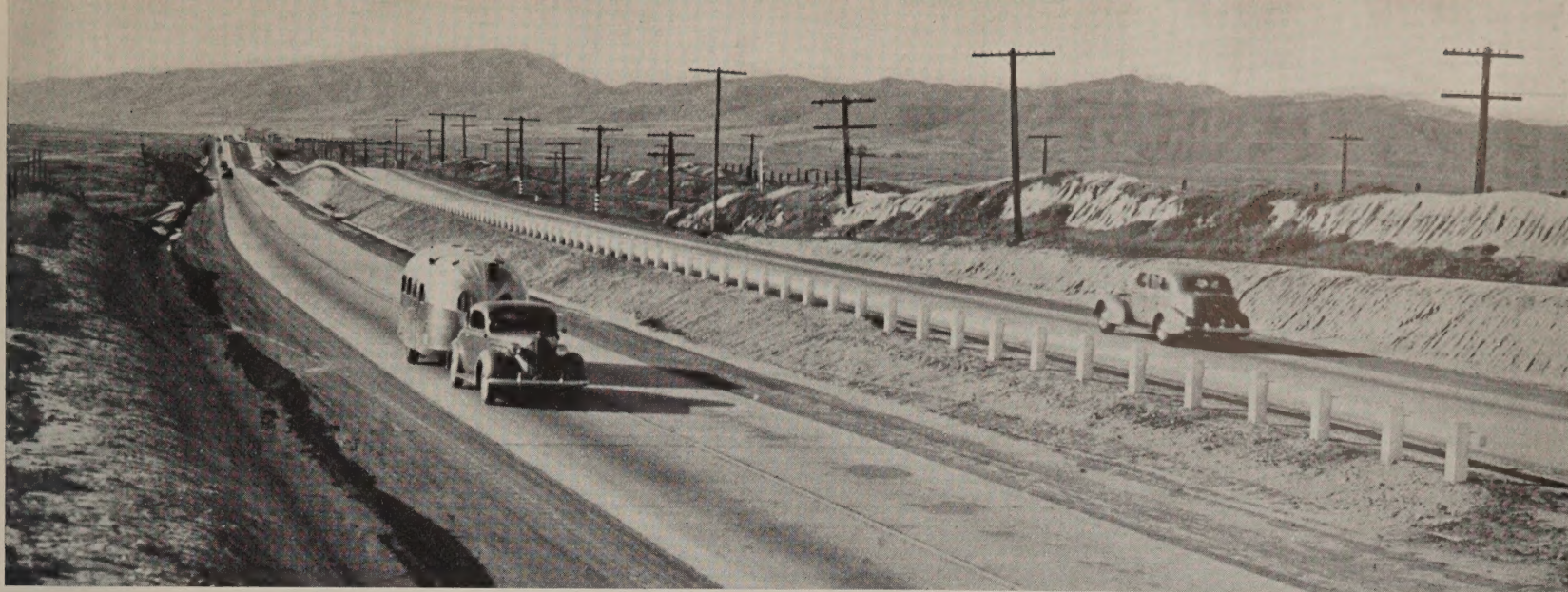
sive bond issues that were expected "to build all the roads California would ever need" and the progress that began and has continued under the gas tax.

"Under the gasoline tax we have been moving fast," he said, "building better, stronger, wider highways and incorporating more safety features, but this is not the end. There are greater things ahead, greater developments for the men and women

phrased a wedding service with the others joining hands and responding "I do" to the "marital" obligations.

CARLSBAD LUNCHEON

Governor Merriam then tied the white ribbons together symbolical of the "wedding" of the counties, and dedicated the new highway "to the use, pleasure and convenience of the people of the counties, the State, the Nation and visitors who come to



The ample separation strip on the four-lane section of new realignment between San Onofre and Oceanside renders head-on collisions practically impossible.

California from nearly all countries in the world."

The official luncheon at Carlsbad was attended by several hundred citizens, city, county and State officials, contractors and chamber of commerce representatives. Leo Carrillo, motion picture star, was master of ceremonies and the "kidding" and sallies of wit and repartee that passed between him and the Governor added much merriment to the occasion.

In his speech Governor Merriam told of the efforts of farsighted men and women of San Diego and Los Angeles who late in the last century talked and dreamed about a highway that would follow the trail of the Franciscan friars all the way north to Sonoma.

Reviewing the difficulties that had to be surmounted through the period of the inadequate bond issues to the

coming of the gas tax financing plan and the progress that has been made since then Governor Merriam said:

"As you know, our highways are built and maintained by gasoline and motor vehicle tax funds. Without the gasoline tax we could not have our vast highway system and without it we could not be dedicating this completed road today. Our gasoline tax moneys must never be diverted to purposes other than highway construction.

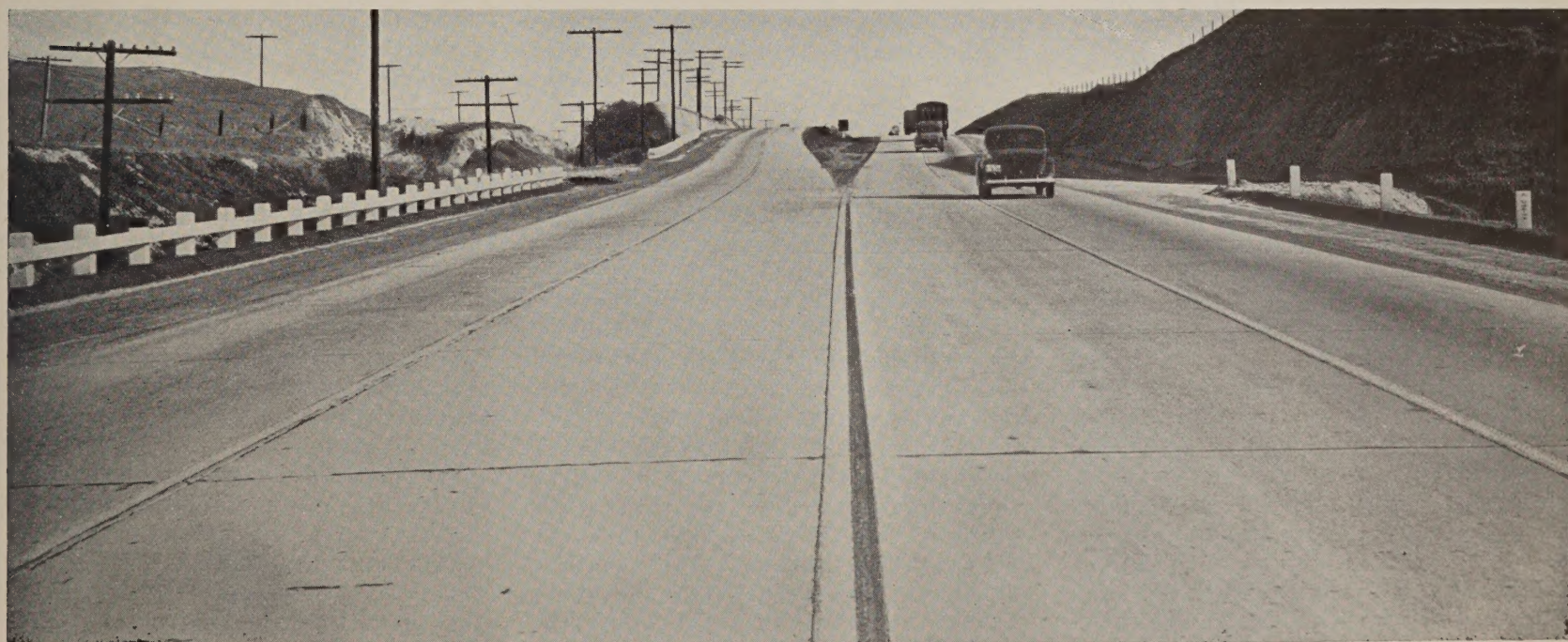
"You can safeguard these funds for all time by a constitutional provision making their misuse impossible. You will have an opportunity to do this at the general election in November."

State Director of Public Works Earl Lee Kelly told the assemblage that the people were to be congratu-

lated in having a Governor who cooperated so zealously in keeping the gas tax funds for roads.

"Since Governor Merriam has been in office more money has been spent on the development of this road than in any other period. It has been developed from a 15-foot road to a highway with three and four 12-foot lanes. The contention that the gas tax fund is so large that a portion of it can be used for other purposes is erroneous. Our traffic has increased from 77,000 vehicles to more than 2,500,000 automobiles, outranking every other State in the Nation. We are now ten years behind in our highway construction program necessary to satisfy present traffic needs."

State Highway Commissioner Hart introduced other dignitaries present and brief talks were made by Assistant Director Hopkins, Commissioner



View of four-lane divided highway section on new realignment of Coast Route (U. S. 101) between Oceanside and San Onofre.



"Wedding of the Counties" was the symbolic theme of the ribbon ceremony at the dedication of the newly completed Oceanside-San Onofre link of Coast Highway as Governor Merriam tied the ribbon joining San Diego and Orange Counties. At left, Mayor A. P. Waibel of Oceanside, State Highway Commissioner W. T. Hart, Supervisor B. A. Sweet and Queen Norma Ellis representing San Diego County. At right, Queen Dorothy Walker and Highway Commissioner P. A. Stanton, representing Orange County.

Stanton, District Engineer E. E. Wallace and H. Matthias, representing the contractors.

Some 3000 people attended the El Camino Real dramatization based on historical facts and incidents that followed the luncheon in which Governor Merriam, Mr. Kelly and Leo Carrillo participated.

CONTRACTS COVERED 18.5 MILES

The progressive improvement in San Diego County to the main State highway connecting San Diego and Los Angeles has been one of the larger programs of the Division of Highways for modernization of arterial routes in Southern California. As important units in such reconstruction several contracts involving work on the 18.5 miles between Oceanside and the Orange County line through the great Santa Margarita Ranch in northern San Diego County have been completed at a total cost of approximately \$1,225,000.

These contracts included improvement to modern standards of alignment and grade with multiple lane pavements providing better facilities for movement of the ever increasing volume of traffic on this important

State route. In the last year or two travel along this portion of El Camino Real reached a volume for which two lanes were inadequate, the daily average ranging from 6,500 to 8,500 vehicles, with many days totaling 10,000 and more cars. In design of the improvements, an ultimate 4-lane divided pavement was adopted as the desired standard and both reconstruction and new construction adapted to fit into such a plan.

WIDENED TO 3-LANE

The first of the contracts for the present improvement to the highway north of Oceanside covered a distance of 7.9 miles, from Eighth Street in Oceanside to the Las Flores Underpass. The work performed under this contract consisted in widening the pavement to provide a 3-lane highway on existing alignment for the southerly 5.4 miles and constructing new 2-lane pavement to serve for southbound traffic only, thus providing a 4-lane divided highway over the remaining portion. The existing pavement, separated from the new pavement was left intact to serve for northbound travel.

The contract also included paving

the approaches to the bridge across Santa Margarita River, which was built under a separate contract concurrently with the road reconstruction; the construction of a bridge across Aliso Creek; and the widening of the bridge across Las Flores Creek. The bridges and their approaches were constructed to 4-lane widths to conform to plans for ultimate standards.

ULTIMATE 4-LANE PLAN

Widening the pavement to three lanes was accomplished by placing a lane of asphalt concrete along one side of the existing Portland cement concrete pavement. Under this method, the plan for future widening will be to place two additional concrete lanes beyond the asphalt so that a divided 4-lane roadway may be obtained by tearing up the center strip of asphalt.

Work on the contracts for the portion of the route from Oceanside to the Las Flores subway was performed by the contracting firm of Wood and Bevanda of Stockton, with the exception of the bridge across the Santa Margarita River, which was erected by Clyde C. Wood, and the approach

fills constructed by Basich Brothers. The largest contract in the improvement north of Oceanside consisted of construction on new alignment of 8.0 miles from the Las Flores underpass to one mile south of San Onofre. On this portion of the route the new highway was placed parallel to and westerly of the tracks of The Atchison, Topeka and Santa Fe Railway, instead of passing under the railroad through the Las Flores Subway on the old alignment and following the base of the hills easterly of the tracks. At the time this revision in highway line was planned, a realignment of a portion of the railroad's line was undertaken to the benefit of both the State and the railway location.

The pavement placed on the new location consisted for the most part of a 3-lane width made of a central lane of plant-mixed asphaltic surface with a lane of Portland cement concrete on each side. Future widening of this section will require only the placing of one additional concrete lane on each edge of the present three lanes which, with the breaking up of the central lane of treated rock surfacing, will provide a 4-lane divided highway.

OLD ROAD ELIMINATED

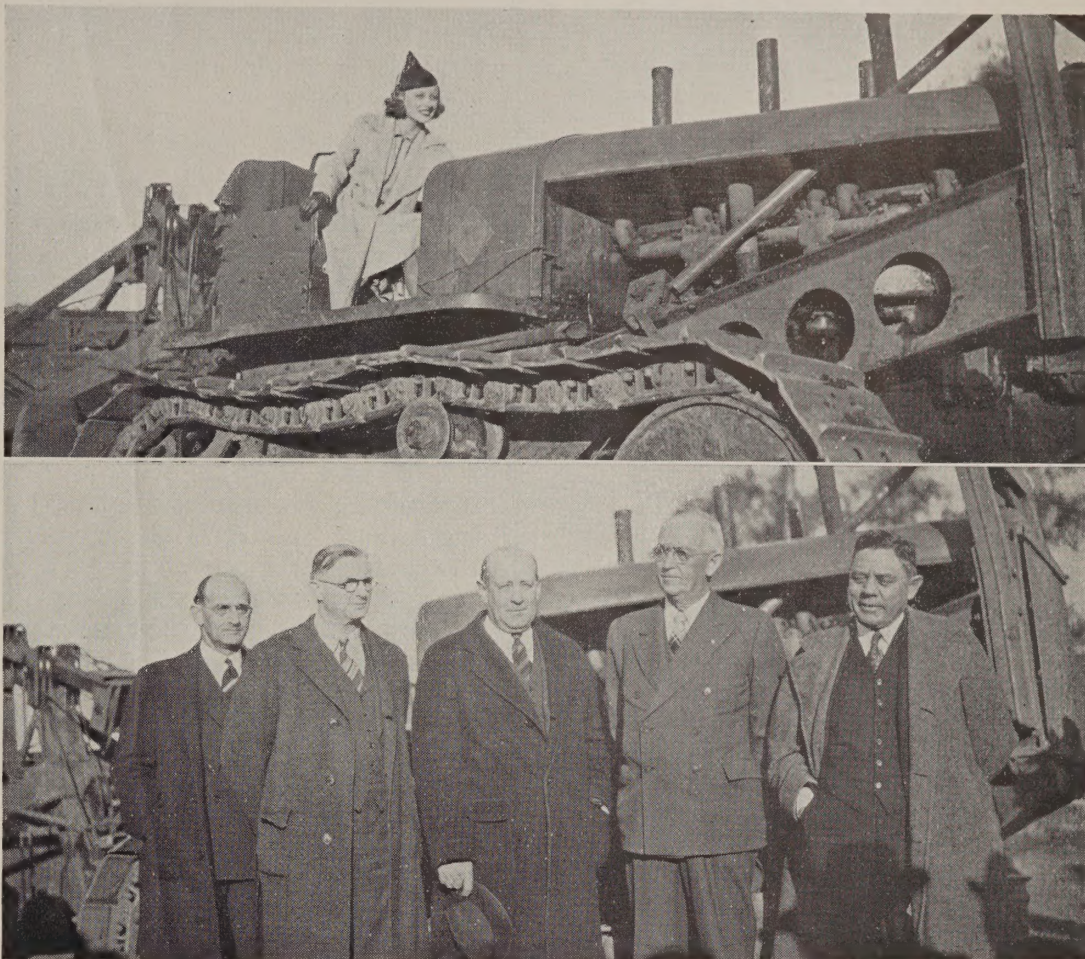
The construction of this eight mile section on new location has eliminated from the State route the substandard portion of the old road which was built at the foot of the hills on a rolling grade.

David H. Ryan was the contractor on this important contract.

At the San Onofre end of the new location the State constructed an overhead grade crossing over the railroad to connect with the existing 3-lane pavement near San Mateo Creek. To effect this location a new bridge across San Onofre Creek was required. Both of these structures were built to a 4-lane standard but the roadway improvement was held to a 3-lane standard on the 2.6 miles from the overhead crossing to the county line, with the exception of necessary transitions at structure approaches.

There were three contracts for construction at this northerly end of the improvement: one for the overhead crossing, one for the bridge over San Onofre Creek and one for the road work. B. G. Carroll of San Diego was the contractor to whom each of these contracts were awarded.

CEREMONIES LAUNCH WORK ON ARROYO SECO HIGHWAY



Scenes at groundbreaking on Arroyo Seco Highway. Upper—Miss Cheryl Walker moves first earth with huge tractor. Lower—Left to right: John C. Jacobs, mayor of South Pasadena; Arthur Kennedy, president Los Angeles City Planning Commission; Roger W. Jessup, chairman Los Angeles Board of Supervisors; E. O. Nay, president Board of City Commissioners, Pasadena; Harry A. Hopkins, Assistant State Director of Public Works.

HOPES and plans of civic leaders of Los Angeles, Pasadena and South Pasadena, sustained and carried to fruition over a period of twenty years, were realized on March 22 when ground breaking ceremonies signaling the start of work on the \$1,327,000 Arroyo Seco Parkway between Los Angeles and Pasadena were held at South Arroyo Boulevard and Sterling Street in South Pasadena.

State and county officials participated in the celebration. Ground breaking ceremonies included brief addresses by Edward S. Graham, President of the Arroyo Seco Parkway Association, who presided; Carl Hinshaw, chairman of the executive committee of the association; Harry A. Hopkins, Assistant State Director of Public Works; Roger Jessup,

chairman of the Los Angeles board of supervisors; A. W. Kennedy, Los Angeles city planning commission; Mayor John C. Jacobs, of South Pasadena; and E. O. Nay, chairman of the board of trustees of the city of Pasadena. Among others on the speakers platform were William J. Fox, county regional engineer, and S. V. Cortelyou, District Highway Engineer.

Actual breaking of ground on the project became a reality when Miss Cheryl Walker, Queen of the 1938 Tournament of Roses, pulled the lever on a giant tractor which moved the first earth on the roadway site.

Following the ceremonies, a breakfast was served at the Pasadena Athletic Club, presided over by Donald C. McCoy, vice president of the Pasadena Chamber and Civic Association.

(Continued on page 27)

Snow Removal Totals 100,000,000 Yards

(Continued from page 16)

that the push plows shortly were of little use.

On February 8, rain fell up to the 6,000 foot elevation, and the packed snow on the pavement turned to heavy slush, making it necessary to concentrate the equipment to combat this condition, as traffic and even the snow removal equipment could make little headway in such going. As the storm continued the rotary equipment began to show the strain, as it was operated continuously except for servicing periods, and breakdowns began to occur.

HANDICAPPED BY BREAKDOWNS

Naturally this further complicated the situation, as breakdowns occur in the heaviest going. This requires moving equipment from another section where it is badly needed, in order to rescue the cripple. In locations where normally one plow only is required, a breakdown for a few hours allows the road to close and may more than double the work of opening the road.

The comparatively high temperatures with occasional rain in the upper elevations caused the snow to pack solidly, although there was little ice next the pavement. Opening the roads, such as the Tahoe-Ukiah route between the Washington Road and junction with U.S. 40, and between Truckee and Tahoe City, was unusually difficult.

In the latter case, twelve hours of continuous operation was necessary to open a section three hundred feet long at Deer Park, where a snow slide had occurred.

COST OVER MILLION

The snow removal work for the 1937-38 season will not be completed for some time, as considerable fall may be expected during April, and opening the closed routes will probably extend well into June in a few cases.

Under the existing program all established communities are provided an outlet, although the more remote places may be snowbound for the duration of a severe storm and even the main roads closed to part or all traffic because of the hazard. In

Mr. C. H. Weeks,
Division of Highways,
Truckee, Calif.

Dear Mr. Weeks:

Perhaps the worst of your work is over for a bit so you can take a moment off to read a few words of commendation I should like to say for the splendid work of your maintenance crews on Highway 40 which you control.

On the night of February 2-3, I had the tremendously interesting experience of spending some 12 hours in the Yuba Pass district, most of it with three of your young snow plow drivers. A broken skid chain stalled me just past Emigrant Gap, and after sending Mrs. Howard and children to Baxters, I stayed with the car. Darn near frozen and blinded in the storm, I was rescued by Driver Wallace and passed on successively to Peters and Lowry. Riding with them I had firsthand opportunity to judge of the work they are called upon to do and to note the skill, the loyalty, and untiring energy they put into their tasks. I won't forget that night. Through the courtesy of these men and of Mr. Hawks, I escaped pneumonia, had my chain fixed, and finally got on my way. Was stalled by other vehicles next morning but hauled out by the Snogo and reached Baxters after lunch on the 3rd.

I'd like to say a word for Wallace, Peters, and Lowry, particularly the former. Men who work 15 hours as cheerfully and competently as these men show that their superiors are the right sort. You have their respect and you have built up a fine organization.

Sincerely yours,

(Signed) I. C. HOWARD

Berkeley, Calif.

view of the need of funds for other purposes and the fact that six cents of every dollar provided for maintenance purposes during the past two years has been expended for snow removal, it seems wise and reasonable to delay expansion of the program into strictly recreational areas.

The hazards may be poor visibility, narrowed roadway, snow slides and blockading of the road catching some unwary traveler in an isolated position. It is to the credit of the field organization that no serious mishap has been recorded this season, although a number of travelers have been blockaded for several hours at different times.

District XI Damage

(Continued from page 13)

washed out due to the high water, and traffic was halted three days until the waters subsided.

On Route 197, west of Ramona, a concrete overflow dip with paved slopes across the Santa Maria River was badly undermined, leaving only the dip shell remaining.

On Route 198, north of El Cajon, the San Vicente Creek overflowed the road, washing out shoulders and short pieces of pavement.

On Mussey Grade, a frame house floated downstream and blocked a 10 by 10 foot culvert, causing a 25-foot section of fill to wash out. Two miles east of Ramona, 80 feet of a concrete overflow dip across the Santa Maria River was washed out.

In Riverside County, two timber trestles across the Coachella Valley Storm Drain were washed out on Route 187. The drain also broke at one place north of Route 204 and the flood waters passed over Routes 203 and 204, depositing thick layers of mud and debris on the pavement and washed shoulders.

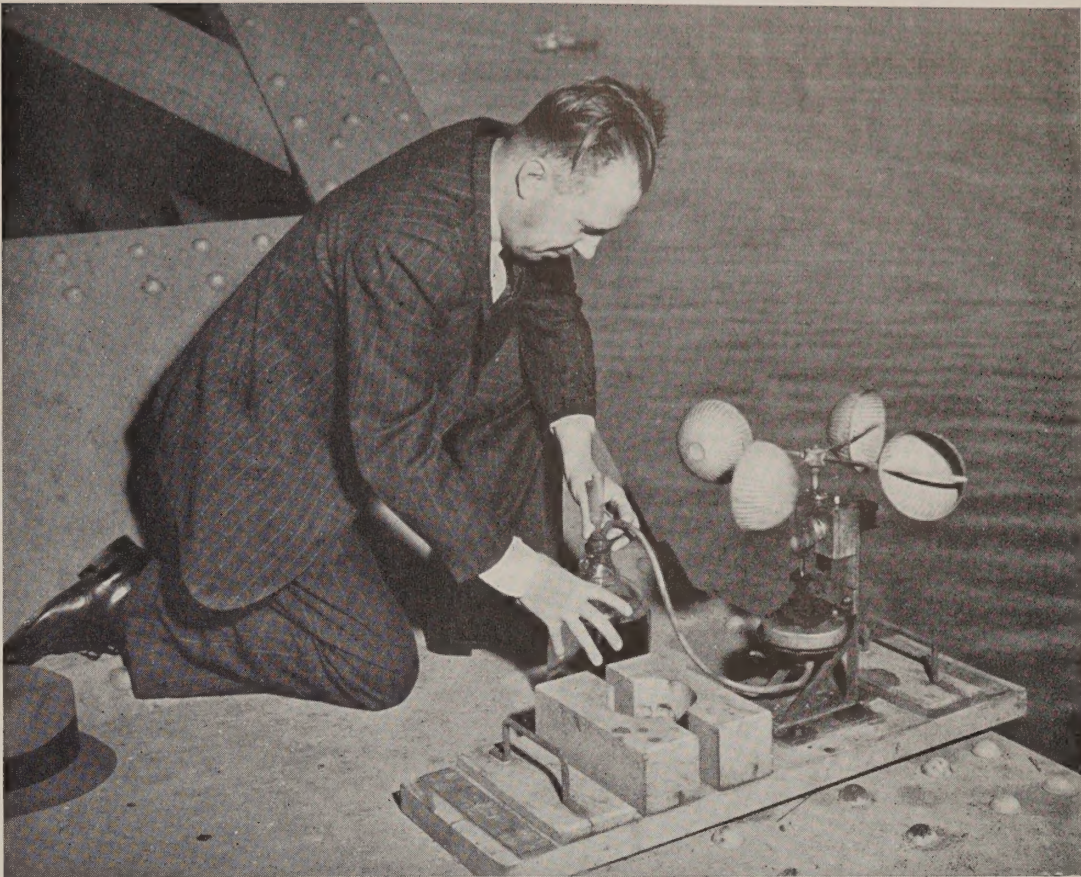
In all cases where traffic was interrupted, it was restored either by temporary repairs or by detours over adjacent roads within three days after the damage occurred, and in all cases except two, within a few hours.

Bay Bridge Is Provided With Air Analyzer

SACRAMENTO laboratories of the Division of Highways have devised an air analyzer for use on the San Francisco-Oakland Bay Bridge, the first ever used on a bridge, it is believed.

The instrument has been placed at the crux of the giant steel cross-beams just below the lower deck at Tower W-2. It works like this: a four-blade scoop-like fan operates a pump which sucks the air into a bottle of distilled water. Thirty revolutions of the fan make one revolution of the pump, scooping up 75 cubic centimeters of air. When the counter on the pump shows up to 99,999 revolutions, the bottle is removed, sealed, and sent to the Division of Highways' laboratories in Sacramento for analysis; 7,500,000 cc. of air can be drawn through the apparatus with accuracy.

First experimental tests, according to Carl Hamilton, Maintenance Engineer of the Bay Bridge, show that the big span breathes an atmosphere consisting, among other things, of sulphates, salt, coffee chaff, and soot.



This instrument is an "air analyzer" used on the San Francisco-Oakland Bay Bridge. Carl Hamilton, Maintenance Engineer of the span, demonstrates its use.

Object of the apparatus is to analyze the air for components destructive to paint.

The air analyzer is being used in conjunction with "washing" tests. So far 120 "spots" on the bridge, of 2½-square feet proportions, have been "washed" by clean cheese cloth

dipped in distilled water. The cloth is wrung dry after the process into a bottle and the water sent to Sacramento laboratories for analysis. From 9 ounces of distilled water approximately 8 ounces are recovered after the washing, according to Mr. Hamilton.

Railway Facilities on Bay Span Nearing Completion

With practically all ties laid east of the Center Anchorage and rails placed east of Pier E-6, work on the construction of electric railway facilities for the San Francisco-Oakland Bay Bridge is progressing rapidly, it is announced by Chief Engineer C. H. Purcell.

Approximately 105,000 California Redwood ties, equivalent to 7,000,000 board feet, will be used on the railway facilities and 15,910,000 gross pounds of track rail. On the bridge proper and the viaduct connecting with the Terminal Building 400,000 spikes will be used, approximating a weight of 320,000 pounds.

He: "I'm almost fast asleep."
She: "That's good, because you're plenty slow when awake."

Bay Bridge Traffic Up Slightly

A SLIGHT increase in traffic over February was announced by State Highway Engineer C. H. Purcell in a March report on the San Francisco-Oakland Bay Bridge filed with State Director of Public Works Earl Lee Kelly.

There was a total of 669,431 vehicles crossing the span last month compared to 594,378 in the preceding period. Daily average was 21,595, up 367 vehicles per day over February. Total vehicles using the bridge to date number 12,380,000.

Three additional days in March over February accounted in part for the increase, Mr. Purcell said, with seventeen rainy days recorded last month.

March traffic totals, however, showed a decrease by 96,884 vehicles from the corresponding period last year. An optimistic note was the increase in freight using the span in March. There were 68,607,331 freight pounds recorded, the largest total since the span opened, except for October, when there were 69,243,169 pounds. The March revenues were \$348,235.23 as compared with \$313,306.17 for February. Comparative totals follow:

	Total March	Total Feb.	Total since Opening
Passenger Autos	617,244	558,239	11,737,625
Auto Trailers	595	513	19,273
Motorcycles	1,895	1,497	41,826
Tricars	1,061	845	11,806
Trucks	35,173	22,983	409,500
Truck Trailers	1,172	878	25,390
Buses	10,586	9,423	133,726
Total Vehicles	669,431	594,378	12,380,851
Extra Passengers	166,045	146,941	2,709,504
Freight Lbs.	68,607,331	54,078,501	926,722,350

\$8,000,000 Damage to Highways

(Continued from page 9)

The district forces are now busily engaged in clearing the various roads for spring traffic.

NORTH SUFFERS AGAIN

The March storm brought added work to the northern districts, still laboring to extricate their roads from the slides and slipouts of the December and January-February storms. To District IV, it brought some 200,000 yards of additional slides, scattered over the Coast Route 56; the Hecker Pass, Route 32; the Bay Shore, Route 68; the Skyline, Route 55; and Routes 42, 44, and 116 leading into the California State Redwood Park near Santa Cruz.

Some eleven additional power shovels and twenty-five trucks were rented and put to work on the repair of these roads. Traffic was delayed for short intervals, and now all of these routes are traversable.

In District X

In District X high water over various roads required the employment of some 125 additional flagmen

to warn traffic. Sections of overflowed pavements on Route 4, north and south of Merced, necessitated the detouring of traffic, as did similar conditions on Routes 122, 123 and the Pacheco Pass road, our Route 32.

Men worked day and night marking the edges of overtopped pavements with lanterns, and holding equipment in readiness to tow the unlucky who might stall their cars in the flood. The same forces and equipment were used in restoring the washed out shoulders and undermined pavement as soon as the waters subsided.

In District VI

In District VI, the counties of Kern, Fresno and Kings took the brunt of the storm as it crossed east of the mountains. Pavements were overtopped and undermined by the flood waters on Route 4, south of Madera; the General Grant Road, Route 41; the Huntington Lake Road, Route 76; and Route 10, west of Coalinga.

South of Madera, on Route 4, Cot-

tonwood Creek overflowed its banks and backed up for more than a mile behind the Southern Pacific Railroad embankment, adjacent the highway. The embankment finally gave way, flooding the highway and forcing the detouring of traffic.

On Route 41, the Kings River again carried away the approach to the structure at Minkler, making the third time this winter that this particular approach has washed out. Route 76, the road to Huntington Lake, was closed by slides and washouts.

On Route 10, west of Coalinga, Waltham Creek washed out three spans of a concrete bridge in the canyon, closing the route. All the routes were again open for traffic in a short time, some 4 power shovels, 55 trucks, 26 tractors, and 31 graders being used in the repair work.

RECORD SNOW FALL

While the districts mentioned were contending with slides and floods, Districts II, III and IX were busily engaged in handling the heaviest snowfalls of the year. During the early weeks of March, some 7 to 20 feet of snow fell in their respective territories. Late reports from District III indicate some 574 inches of snow for this season, 434 inches of which has fallen since February. Again in District IX, some 260 inches came down in the same period with a record of 300 inches for the season.

The response of the Maintenance organization to the March challenge has been a source of pride to the Division of Highways. This storm, which within a few days time damaged State highways to the extent of \$4,000,000, was the heaviest within our experience.

While practically all of these routes are now open, months will be required for their final repair. It is hoped that the public will not be too critical of road conditions pending the completion of this work.

Visitor: "How do you manage to live during this depression?"

Farmer: "Well, last year we lived by faith, this year we live in hope, and next year we plan to live on charity."



House washed onto highway on E Street near city limits of San Bernardino.

Elevating Grader Cuts Down Road Excavation Costs

By H. B. MILNER
Resident Engineer

THE constant improvement of earth moving equipment is one of the reasons for increased efficiency in highway grading operations and for lower unit prices for excavation.

The development of the elevating grader has kept pace with the improvement of other earth moving equipment and today, in its own special field, it is still considered supreme as an economical method of excavating.

The modern machine differs but little from the older types in basic design, but improvements and modifications have increased its efficiency. Powerful tractors are now used as motive power, replacing the horses and mules of the old era, and the belt is operated by an independent motor.

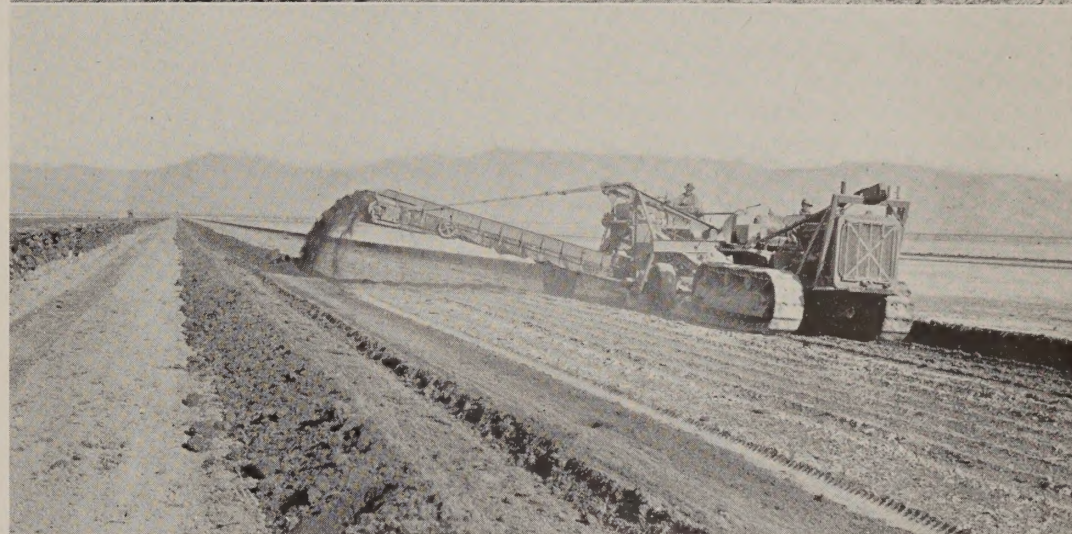
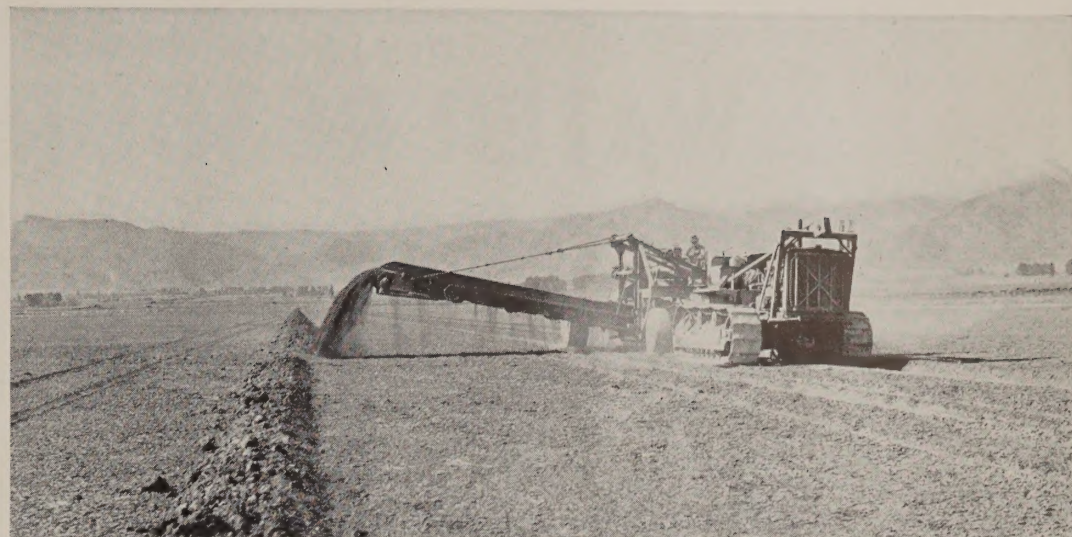
MODOC HIGHWAY WIDENED

The ideal set-up for this type of machine was furnished on the contract completed by Poulos & McEwen, contractors, for widening the roadbed and constructing protective dykes across the dry bed of Middle Lake near Cedarville, in Modoc County, about 1.4 miles in length.

The original roadbed was confined by vertical rock walls averaging three feet in height and was dangerous to traffic, particularly in winter when snow and poor visibility increased the hazard.

The improvement eliminated this condition by widening the roadbed three feet on each side and providing gentle slopes to the fills. During occasional wet seasons the lakebed is covered with a foot to eighteen inches of water and the high winds sweeping up and down the valley drive the water from one end of the lake to the other and cause considerable wave action.

To prevent erosion of the newly constructed fills, protecting dykes were thrown up on each side of the roadway about 160 feet from the cen-



1—Elevating grader constructing protective dyke across head of Middle Lake in Modoc. 2—Grader delivering roadside material for widening roadway across bed of Middle Lake. Rock wall bordering present road shown at left.

ter line extending entirely across the lake-bottom. Several gaps 50 feet long were left in these levees and short levees were built opposite these gaps. This permits the passage of water from one side of the road to another, through culverts under the road, and still protects the shoulders of the road against waves.

An elevating grader, with an auxiliary motor for operating the 48-inch by 35-foot belt, and drawn by a 75-horsepower tractor, was used on the work. A heavy motor grader with a 12-foot blade spread and compacted the windrows placed by the grader.

LOW EXCAVATION COST

The machine excavated at an average rate of 500 cubic yards per hour, actual working time, although the contractors claim to have considerably exceeded this output on previous jobs. Nearly 38,000 cubic yards of material were placed at a contract price of ten cents per yard.

Elevating graders function best

when excavating along the roadside and delivering to the fill by means of a belt, usually about 35 feet long. In flat borrow pits they are the most economical equipment for loading excavated material into trucks. Although their field of operation for the elevating grader is limited, their usefulness and efficiency on projects such as this are quite pronounced.

On another highway contract in Siskiyou County similar equipment moved material into the fill at the rate of over 5000 cubic yards per 8-hour day.

An old darky visited a doctor and was given definite instruction as to what he should do. Shaking his head he was about to leave when the doctor said, "Here, Rastus, you forgot to pay me."

"Pay you for what, boss?"

"For my advice," replied the doctor.

"No, suh! I ain't gwine to take it," and Rastus shuffled out.

Salesman: "How would you like some nice horseradish today?"

Lady Customer: "No thank you. We have a car."



THE Division of Water Resources representing the Water Project Authority of the State of California, has continued engineering studies and negotiations in connection with the construction of the Central Valley Project under a cooperative work agreement with the U. S. Bureau of Reclamation. Under this agreement negotiations have been carried on with the owners of lands in the San Joaquin Valley for the acquisition of such lands and water rights as are needed for the project.

Construction work by the Bureau of Reclamation on the project was somewhat delayed by weather conditions. However, work was continued and considerable progress made on the construction of the Contra Costa Canal and the government camp for the Shasta Dam.

IRRIGATION DISTRICTS

The recent severe storms producing heavy runoff and causing considerable damage to agricultural interests in the valleys from floods, will prove beneficial in many respects to areas dependent upon summer irrigation for maturity of crops. Most of the large storage reservoirs are nearing or have already reached the spilling stage and the abundant snow pack in the mountains insures ample summer flow for those districts dependent upon direct diversion for their water supply.

CALIFORNINA COOPERATIVE SNOW SURVEYS

The storm period that began late in January, with storm after storm arriving in quick succession from the Gulf of Alaska, did not come to an end until the middle of February. After the deep accumulations of new snow had had time to settle sufficiently to allow of travel, men on skis and webbed snow shoes were sent out from different parts of the State to measure at various locations the increase in the snow pack due to the extended storms.

Further routine progress snow surveys were made at key snow courses during the last few days of February and the early days of March, by employees of the Divi-

sion of Water Resources and those other organizations and parties participating in the field work of the California Cooperative Snow Surveys.

The results show that at the end of February, in every watershed of the Sierra the snow pack was in excess of the normal quantity to be expected by that date, while in those watersheds north of the American River, the snow pack was even then ahead of the normal snow pack to be expected by the first of April.

SUPERVISION OF DAMS

Our records disclose that all dams came through the severe floods without failure in major degree.

Work is progressing at a very rapid rate on the construction of the Copper Basin Dam of the Metropolitan Water District, Los Angeles, located in Copper Basin, tributary to Colorado River, in San Bernardino County.

With the opening up of the season in the Mono Basin, work will be resumed on the Long Valley and Grant Lake dams owned by the city of Los Angeles.

WATER RIGHTS

Supervision of Appropriation of Water.

Twenty applications to appropriate water were received during February, of which two of considerable importance were those of the Oakdale Irrigation District to appropriate 93,000 acre-feet per annum by storage at Beardsley Flat Reservoir site on Middle Fork of the Stanislaus River for irrigation and power purposes at an estimated cost of \$2,900,000. During the month 13 applications were denied and 13 permits were issued. During the same period 9 permits were revoked and the rights under 7 were confirmed by the issuance of license.

SACRAMENTO-SAN JOAQUIN WATER SUPERVISION

During the past month activities have been wholly in the office assembling the field data gathered during the summer months in order to compile a mimeographed report showing the diversions, acreage irrigated, stream and return flows in the Sacramento and San Joaquin valleys.

The sampling of water in the delta for salinity is being carried on at all regular stations to record the retreat of salinity.

FLOOD CONTROL AND RECLAMATION

Maintenance of Sacramento Flood Control Project.

During this period extremely high stages were reached in the flood channels of the upper Sacramento Valley, and it was necessary to maintain full patrol day and night from March 18th to March 28th.

Relief Labor Work.

During this period about 70 relief laborers were employed in patrolling levees and in miscellaneous emergency work and, in addition, for about five days a crew of 50 men was stationed at Colusa for emergency work. It was not possible to continue with channel clearing work on the Feather River during this period, on account of high water.

Sacramento Flood Control Project.

The work of removing the levees in the Feather River overflow channel south of Marysville in District 784 was completed during this period at a cost of approximately \$18,000. A small amount of work remains to be done, which will be deferred until the weather is favorable. Construction of the timber bridges in the Dry Creek project near Wheatland has continued and all will be completed within about ten days.

Emergency Levee Repairs.

Under Executive Order No. E 177 work is continuing in making repairs to levees in Glenn, Shasta, Butte and Tehama counties, and at this date approximately \$60,000 has been expended out of the total of \$150,000. The work is now proceeding rapidly due to the favorable weather, and it is expected that all work will be completed by April 20th.

With the money provided by the State emergency fund, this office has undertaken the protection and patrol of the levee on the west bank of the Sacramento River from Colusa to Butte City. A number of breaks were prevented during the extremely high water commencing on March 18th.

Levee protection work along the San Joaquin River south of Stockton was commenced on March 16th under an emergency allotment of \$20,000, and is still under way. During this period a number of levee breaks were averted with the assistance of State forces, on Roberts Island, the Stewart tract, Reclamation District No. 17, the Fink tract, and on the levee between Paradise cut and the Banta-Carbona irrigation intake.

R. M. Gillis Wins Promotion to Post of Construction Engineer

MR. R. M. GILLIS, for the past five years District Engineer of the Division of Highways at Fresno, has been promoted to the position of Construction Engineer, the position left vacant by the death of Mr. C. S. Pope.

Mr. Gillis is a graduate of the Massachusetts Institute of Technology and has had long experience in engineering work with an outstanding record in highway engineering, particularly in Washington and California.

He was first employed in California on April, 1929, as Assistant District Engineer, District X, and on November, 1929, he was promoted to the position of Assistant Construction Engineer at Headquarters; in 1935, he was promoted to District Engineer at Fresno.

He brings with him to the new position a thorough knowledge of both the District and Central Office problems, a wide acquaintance among the highway personnel and a proven ability in highway construction.

Mr. Earl T. Scott, who for the past three years has been District Maintenance Engineer in District VII, has been promoted to the position of District Engineer at Fresno.

Mr. Scott is a graduate of Stanford University with approximately 22



R. M. GILLIS

years of experience in highway engineering. He has been with the Division of Highways since 1914 with the exception of 19 months during the World War when he was in the service and approximately nine months beginning in July, 1921, when he accepted employment with the U. S. Bureau of Public Roads. He has had experience in all phases of highway engineering.

nineteen-foot spans and grading approaches and applying road-mix surface treatment thereto. District IV, Route 56, Section D. Peter J. McHugh, San Francisco, \$17,942; Franzini and Fredenburg, San Rafael, \$18,372; A. Soda and Son, Oakland, \$20,503; Palo Alto Road Materials Co., Palo Alto, \$20,564; Parish Bros., Los Angeles, \$20,735; Chas. L. Harney, San Francisco, \$20,743; Lee J. Immel, Berkeley, \$21,057; B. A. Howkins and Co., San Francisco, \$21,705; C. C. W. & H. H. Haun, San Francisco, \$21,785; E. T. Lesure, Oakland, \$23,769; E. A. Forde, San Anselmo, \$19,055; Valley Construction Co., San Jose, \$19,859; Pacific States Construction Co., San Francisco, \$19,931; Clausen and Corfield, Berkeley, \$20,842; F. J. Maurer and Son, Inc., Eureka, \$20,930; Claude C. Wood, Stockton, \$21,680. Contract awarded to Albert H. Siemer and J. Carcano, San Anselmo, \$17,220.50.

MONTEREY COUNTY—Between five miles and 5.9 miles west of Greenfield, about 0.9 mile to be graded. District V, Feeder road. Young and Son Co., Ltd., Berkeley, \$16,802; Mountain Construction Co., Sacramento, \$17,435; M. J. Ruddy, Modesto, \$17,640; Bodenhamer Construction Co., Oakland, \$24,609; Guerin Bros., San Francisco,

Arroyo Seco Highway

(Continued from page 21)

The Arroyo Seco Highway will follow down the Arroyo Seco, from Pasadena, through Victory Park, skirt the back edge of Sycamore Grove, and connect with San Fernando Road and North Figueroa Street leading to the center of metropolitan Los Angeles. When completed, the highway will be one of the most modern in the nation. There will be no grade crossings throughout its entire length.

A total of \$1,112,000 has been allocated for the Arroyo Seco project. The contract now under way calls for the expenditure of \$118,000 and includes the construction of three bridges and two blocks of grading.

\$24,549; John Jurkovich, Fresno, \$22,724; Chas. L. Harney, San Francisco, \$20,694; Valley Construction Co., San Jose, \$21,750; George K. Thompson and Co., Los Angeles, \$20,640; L. C. Karstedt, Watsonville, \$17,493; Claude C. Wood, Stockton, \$23,156; George J. Bock Company, Los Angeles, \$24,294; Martin Bros. Trucking Co., Long Beach, \$31,045; Triangle Rock and Gravel Co., San Bernardino, \$28,676; N. M. Ball Sons, Berkeley, \$21,757; Granfield, Farrar and Carlin, San Francisco, \$19,623; Harms Bros., Sacramento, \$17,963; Minnis & Moody, Los Angeles, \$19,997. Contract awarded to J. L. Conner and Sons, Monterey, \$15,317.16.

NAPA COUNTY—Three bridges, one across Dry Creek, one across Bale Slough Overflow and one across Bale Slough, between 6 and 15 miles north of Napa to be widened. District IV, Route 49, Sections B, C. M. J. Lynch, San Francisco, \$20,359; C. W. Calleti and Co., San Rafael, \$23,360; Claude C. Wood, Stockton, \$21,012; Carl N. Swenson Co., San Jose, \$21,950; Brown and Lambretti, Mill Valley, \$21,998; Peter J. McHugh, San Francisco, \$24,059; Pacific States Construction Co., San Francisco, \$24,339; Rock and Gravel Trucking Co., Oakland, \$24,402; C. C. W. & H. H. Haun, San Francisco, \$26,412. Contract awarded to Palo Alto Road Materials Co., Palo Alto, \$19,947.93.

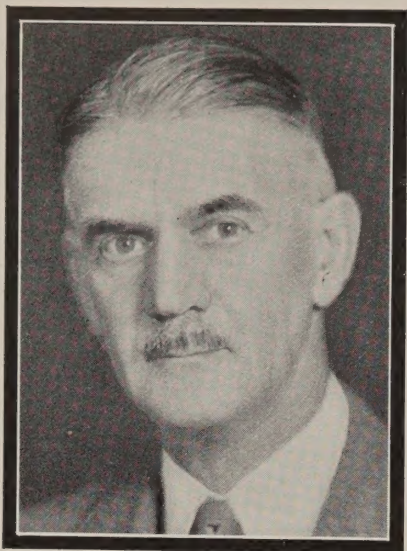
SAN BENITO, MONTEREY, SAN LUIS OBISPO, SANTA BARBARA COUNTIES—At various locations, diesel oil to be applied to roadside vegetation for a distance of about 242.6 roadside miles. District V. Pacific Truck Service, Inc., San Jose, \$8,418; Lee J. Immel, Berkeley, \$7,797; Western Motors Transfer Co., Santa Barbara, \$10,660; Oilfields Trucking Co., Bakersfield, \$7,624; L. A. Brisco, Arroyo Grande, \$9,970; Bradley Truck Co., Inc., Santa Maria, \$9,125. Contract awarded to Bert Hale, Pismo Beach, \$6,658.50.

TULARE COUNTY—Between Morton Street in Porterville and Mulberry Street, about 0.9 mile to be graded and surfaced with plant-mixed surfacing on crusher run base and road-mix surface treatment to be applied to the shoulders. District VI, Route 129, Section Ptry, C. Oilfields Trucking Co., Bakersfield, \$40,819; Griffith Co., Los Angeles, \$34,693; Piazza and Huntley, San Jose, \$36,223; Union Paving Co., San Francisco, \$41,217. Contract awarded to N. M. Ball Sons, Berkeley, \$33,235.60.

Highway Bids and Awards for March, 1938

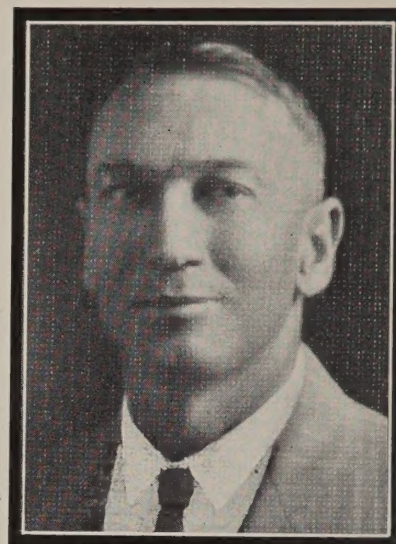
LOS ANGELES COUNTY—Two bridges, an equestrian and pedestrian subway with approaches to be constructed on Arroyo Seco Parkway between Arroyo and Grand Avenue. District VII, Route 205, Section S. Pas. C. O. Sparks and Mundo Engineering Co., Los Angeles, \$117,158; John Strona, Pomona, \$123,883; Oscar Oberg, Los Angeles, \$110,848; Griffith Co., Los Angeles, \$113,251; Claude Fisher Co., Ltd., Los Angeles, \$112,886; George J. Bock Co., Los Angeles, \$120,930; Byerts & Dunn, Los Angeles, \$112,629; Oswald Bros., Los Angeles, \$130,892; W. E. Hall Co., Alhambra, \$116,959; Minnis & Moody & Werner & Webb, Los Angeles, \$119,968; Carlo Bongiovanni, Los Angeles, \$118,049; United Concrete Pipe Corporation, Los Angeles, \$114,211; Fred E. Potts Co., Los Angeles, \$121,716. Contract awarded to J. E. Haddock, Ltd., Pasadena, \$109,837.40.

MARIN COUNTY—A timber bridge with concrete deck across Stemple Creek, about one mile north of Tomales consisting of 11



Charles Stockton Pope

In Memoriam



Samuel Alexander Hart

Charles Stockton Pope, Construction Engineer of the Division of Highways since 1923, passed away on March 16, 1938, at Riverside, while on an inspection trip of recent storm damage to highways in southern California.

Mr. Pope was born August 10, 1874, at Fort Stockton, Texas, the son of Dr. Benjamin F. Pope, a distinguished surgeon in the U. S. Army. He received his early education at army schools, private and public schools, graduating from Stanford University with an A.B. in C.E. in 1897. While at Stanford, he was a member of the Chi Psi fraternity, varsity track team in 1896 and 1897, and was elected perpetual class president in his senior year.

Mr. Pope began his professional career in 1898, on land and irrigation surveys in Kern County. In 1900 and 1901 he was assistant engineer on power projects for the Standard Electric Co., continuing similar work in 1902 and 1903 for the North Shore Railroad and Stanislaus Water and Power Co. During 1904 to 1906 he was engaged as surveyor for the King of Arizona Mine, and in private practice at Los Angeles. In 1907 he entered the engineering department of the city of Los Angeles where he was principally engaged as highway engineer in charge of paving work until the year 1915. From 1916 to 1921 he was associated with Warren Brothers as district engineer on promotion and consulting work for asphalt pavement projects in California and Nevada.

In January, 1922, he began his service with the California Highway Commission as Assistant Engineer, specializing on asphalt pavement work. In September, 1923, when the Construction Department was organized, Mr. Pope was appointed head of this department as Construction Engineer in charge of the Materials and Research Laboratory and of all highway construction, except major bridges. The laboratory assignment was terminated in 1928 when the Materials and Research Department was organized. As Construction Engineer, Mr. Pope also had charge of the State Prison Camps, involving supervision of the construction of many miles of heavy mountain roads and of problems concerning the rehabilitation of prisoners.

To his keen, analytical mind and his constant interest in research can be attributed many of the improved methods of construction of our highways. His continued effort and study are primarily responsible for the development of the modern high type asphalt concrete pavement as now constructed by the State. His numerous technical and scientific papers, articles, and discussions contributed materially to the knowledge of highway engineering and are widely recognized as authoritative.

He was an active member of the American Society of Civil Engineers, serving as president of the Sacramento Section in 1924 and on numerous committees. He was also a member of Sacramento Lodge No. 40, Free and Accepted Masons, the Sutter Club, San Francisco Engineer's Club, California Museum Association, and a former member of the Sutter Tennis Club and the Del Paso Country Club.

Early on Sunday morning, March 20, 1938, Samuel Alexander Hart succumbed to the effects of a long illness at his home in Sacramento, California. Although in poor health for a number of years, he had continued his duties in the office of the State Engineer as Senior Engineer, Supervision of Dams, till less than three weeks before his death.

The son of Henry Eldredge and Anzolette (Hayward) Hart, he was born at Stockbridge, Wisconsin, December 14, 1885, where he received his early education. In 1903 he came to California and completed his preparation for college, entering the University of California with the class of 1910, but the necessities of self support prevented his graduation until 1911 when he received his B.S. degree.

Although he graduated in mining, Mr. Hart chose to follow irrigation and hydraulic engineering, devoting the major portion of his professional career to these two branches.

From the time of his graduation until the United States entered the World War, he followed engineering work in Northern California and Arizona, served as Chief Engineer of the Waterford Irrigation District for three years; Assistant Engineer of the South San Joaquin Irrigation District for two years, chiefly on the construction of Woodward dam. After the war he was employed in private practice with Joseph W. Gross, Consulting Engineer, for fifteen months, a few months with the State Division of Engineering and Irrigation on reconnaissance surveys and from February, 1922, to November, 1928, he was employed in the Engineering Department of the City of Sacramento, rising from the position of Assistant Engineer to that of City Engineer. From November, 1928, to April, 1930, he served as Sanitary Engineer for the City of Berkeley in charge of the design and construction of a storm sewer system. Upon completion of this work he was appointed to the position of Senior Engineer of Hydraulic Structure Design on Supervision of Dams in the Division of Water Resources, Department of Public Works, continuing in this position till his death.

Mr. Hart joined the war forces of the United States in August, 1917, and was commissioned First Lieutenant of Co. H, 23rd Engineers. The regiment went overseas on March 30, 1918, and was engaged for the greater part of the time in building and maintaining communications to the front lines. The regiment took an active part in the battles of St. Mihiel and the Meuse-Argonne, returned to the United States and was disbanded in June, 1919, Mr. Hart receiving his honorable discharge on the 17th of that month.

On August 5, 1921, he married Elsie A. Silman who, with their two sons, Samuel A. Jr., and William E., survives him.

Mr. Hart was a member of Union Lodge No. 58, Free and Accepted Masons of the State of California, the Scottish Rite Bodies of Sacramento and the Ben Ali Shrine. He was also a member of the American Society of Civil Engineers and affiliated with the Sacramento Section. His friendly greeting and genial smile will be missed by his friends and associates.

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MAP
SHOWING
STATE HIGHWAY SYSTEM

LEGEND
Primary Roads ———
Secondary Roads - - - - -



See Detail Map

SAN FRANCISCO AND VICINITY

See Detail Map

LOS ANGELES AND VICINITY

